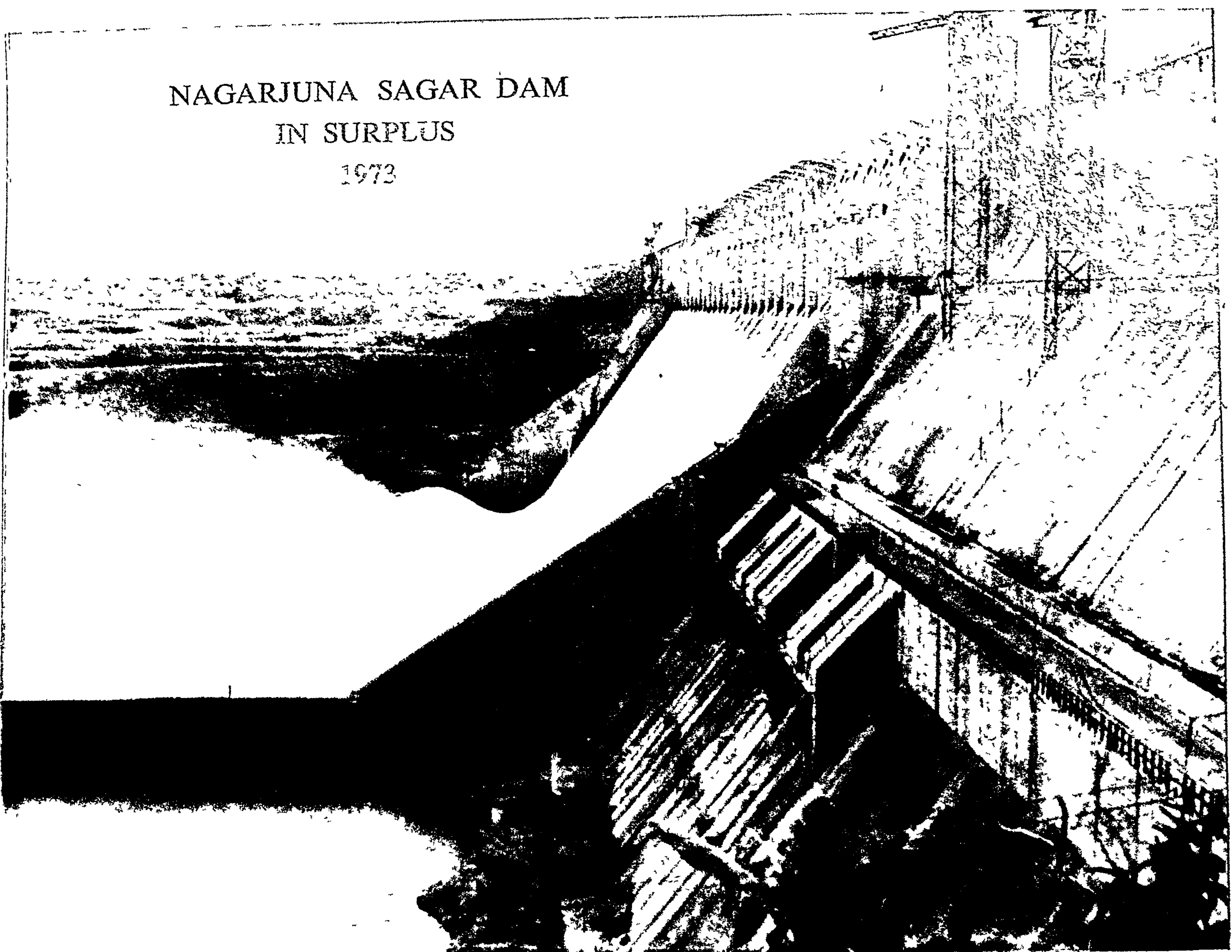

NAGARJUNA SAGAR DAM
IN SURPLUS
1973

NAGARJUNA SAGAR

THE EPIC OF A GREAT TEMPLE OF HUMANITY

WORLD'S LARGEST MASONRY DAM

M. GOPAL RAO, F. I. E.,
Former Chief Engineer, Consultant, Government of India,
Chairman, A. P. State Construction Corporation.



1979

BHARATIYA VIDYA BHAVAN

KULAPATI K M. MUNSHI MARG

BOMBAY-400 007

In India,	price :	Rs.	75
„ U K.	price :	£	7
„ U.S.A.	price :	$	12

PRINTED IN INDIA
BY T DURAI, AT THE DIOCESAN PRESS, MADRAS 600 007 AND PUBLISHED BY
S. RAMAKRISHNAN, EXECUTIVE SECRETARY, BHARATIYA VIDYA BHAVAN
BOMBAY-400 007—1979 C9030

DEDICATED

To

Jawaharlal Nehru

the architect and builder of modern India,
who laid the foundation-stone of this project,

and

the many martyrs whose supreme sacrifice
and the millions whose dedicated labour
made it possible to convert the dream
of generations into a reality.



When I lay this foundation stone here of this Nagarjunasagar, to me it is a sacred ceremony This is the foundation of the Temple of Humanity of India, a symbol of the new temples, that we are building all over India

Dec 12, 1955 **Jawaharlal Nehru**



This reference volume is not only of historical importance, but will also serve as a source of inspiration for generations

May 9, 1979 **Dr. N. Sanjiva Reddy**



राष्ट्रपति भवन नई दिल्ली भारत

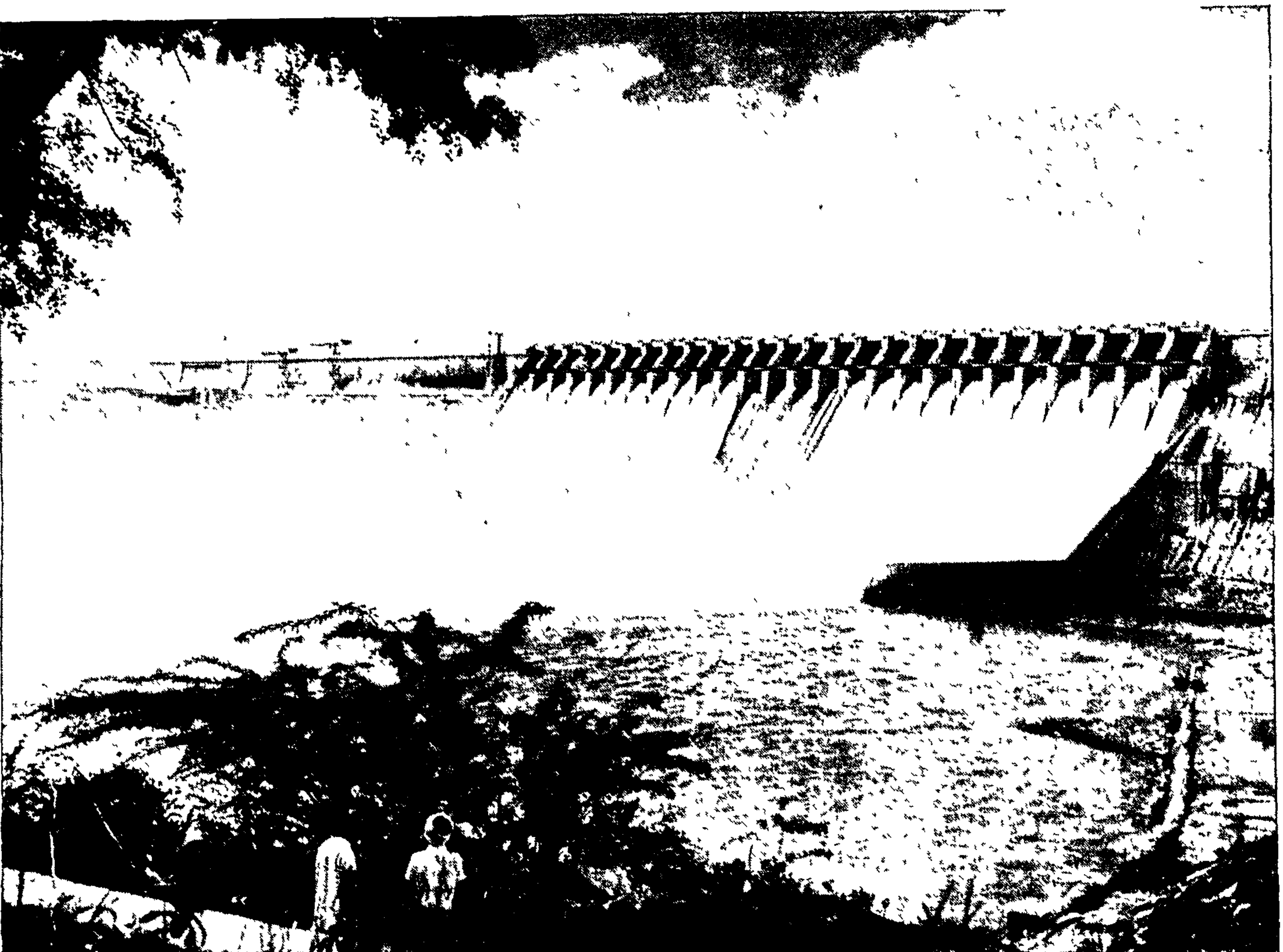
RASHTRAPATI BHAVAN NEW DELHI INDIA

FOREWORD

This book is an excellent compendium of reference material on the various technical and administrative aspects of the Nagarjunasagar Project. This irrigation-cum-power project is the world's largest masonry structure conceived, designed, and built entirely with Indian technical and organisational expertise. The project was initiated when I was Deputy Chief Minister in-charge of the Public Works Department of the then Andhra State The foundation stone of the project was laid by the late Prime Minister Shri Jawaharlal Nehru in 1955

A unique feature of the Nagarjunasagar project is that the use of sophisticated mechanisation was minimal as compared to the enormous labour force employed on this gigantic enterprise The project which will benefit millions of our people and which is fast transforming once barren arid land into a green and smiling countryside owes everything to the courage, determination, and dedication of a human task force drawn from all parts of the country and who worked with devotion to make the project a success.

Shri M Gopal Rao, himself a dedicated engineer, was associated with the project from the beginning and has detailed knowledge of the problems which the project faced at various stages in its construction This reference volume is not only of historical importance, but will also serve as a source of inspiration for generations, who will face the challenges of the future elsewhere with the same spirit and ardour.



View of Nagarjunasagar Dam (Completed)



It is a matter of pride that no foreign consultants were associated with this gigantic project of national and international significance

July 9, 1977

Dr K. L. Rao

INTRODUCTION

I am very glad to know that my friend Mr. M. Gopal Rao, an eminent engineer of our country, has brought out a unique and comprehensive book on Nagarjunasagar Project The value of the publication can be gauged by the fact that right from the laying of an approach road and designing, to the completion of the gigantic dam, Mr. Gopal Rao, was fully associated with this project. This is a tribute to his hard and brilliant work, his qualities of leadership and his spirit of friendliness with various wings of the department and persons of different kinds.

This book has many interesting historic and technical features. His approach to the problems and their solutions to various difficulties that arose during the progress of the work is exemplary. The question of arranging materials of construction, the co-ordination of various organizations, taking co-operation of eminent engineers and officers connected with the task and the question of handling the uncontrolled waters of the Krishna during the construction period without impeding the work on hand, have been tackled in a very smooth and satisfactory manner during its 12-year construction period. The smooth conduct of the work and the team spirit displayed by engineers and workmen bear testimony to Mr Gopal Rao's dynamism.

In spite of strong suggestions for building this high dam in concrete, the Expert Committee of Indian Engineers had decided to build it in masonry on consideration of economy and employment Nagarjunasagar Dam, the largest masonry structure of the world, has employed as many as 40,000 workers for more than ten years in this colossal work of huge magnitude.

The quality control of the dam must be of a very high order. The work requires a very close supervision over various officers round the clock whether it is mid-day or mid-night. The excellent quality of work done at Nagarjunasagar can be seen from the fact that the seepage is much less than that of even a concrete dam of a similar height.

When there was the problem of rehabilitation of people, who were affected by the submergence of the dam, it required a very careful handling. It required day-to-day touch with the affected families who should be given immediate relief. The various problems connected with this work were tackled promptly and successfully.

I am sure that this book will be immensely useful to students and engineers and will be read with interest by the general public. The book tells the fascinating story of how a devoted engineer with hard work and imagination could achieve wonders by common sense and sympathetic approach to ticklish problems on the spot, with good humour. Mr. Gopal Rao is an exemplar of this.

It is a matter of pride that no foreign consultants were associated with this gigantic project of national and international significance. I hope, succeeding generations would greatly benefit from this purposeful and illuminating book.

DR K. L. RAO

Former Union Minister for Irrigation & Power, Government of India.

July 9, 1977

PREFACE

The Author has the proud privilege to present this book, Nagarjunasagar—the epic of a Great Temple of Humanity. Nagarjunasagar is unique, it is unlike many other dams in post-independent India and, in fact, in the world. It is unique, not only as a major hydraulic structure harnessing the Krishna—a mighty river in India, not only as the world's largest masonry structure, not only as creating the largest man-made lake in India, but also as it represents the unique example of massive participation of human effort of people of different parts of India in its construction, thus making it verily a national and precious monument unprecedented both before and after.

With its gigantic volume of masonry, having the largest water holding capacity in India, it has a rare and fortunate feature having its foundation been laid by the architect of modern India, Sri Jawaharlal Nehru and its waters having been released by his worthy and dynamic daughter Srimathi Indira Gandhi in the same capacity as the Prime Minister of India. As a great irrigation and power project of India, it is a gift of Sri Jawaharlal Nehru to the peasants of the backward and arid regions of Andhra Pradesh. It revolutionised the economic and social structure of these unfortunate people who became self-sufficient in food and are creating granaries of food grains for exporting to other parts of our country and abroad.

This book deals with the techniques of construction, which were adopted by the outstanding engineers of India, to serve as a reference to posterity, as a guide to students, as reference to serving engineers and contractors engaged in similar construction and to the general public

It was over two decades ago, that I, as the Divisional Engineer heading the Nandikonda Survey Division, was assigned the task of detailed investigations of the Nandikonda Project. At that time, little did I realize that I would be associated with the construction of this largest masonry structure of the world, right from its inception to completion. Nor, did it ever occur to me that I would be its authentic biographer.

There was a village named Nandikonda, which was on the upstream of the present dam. The Dam was first named after the village as Nandikonda Dam. It now stands submerged The Dam has been renamed as 'Nagarjunasagar Dam' in memory of the great Buddhist

sage and savant Acharya Nagarjuna, who lived and shed light in this region during the second century A.D I have named this book as 'The Epic of a Great Modern Temple' inspired by the words of Shri Jawaharlal Nehru, who said while laying the foundation of Nagarjunasagar Dam on December 10, 1955, 'when I lay the foundation stone here of this Nagarjunasagar, to me it is a sacred ceremony. This is the foundation of the temple of humanity of India, a symbol of new temples that we are building all over India'.

It was in the year 1954, that my aged parents Sri Matur Appa Rao and Srimathi Venkatamma were taken in a bullock cart to the Nandikonda Dam site After a holy bath in the river, we offered prayers for the early sanction of the project. Later, when the construction was started, they were staying with me at the dam site. My father passed away in 1959 and my mother in 1964. They were cremated on the banks of the Krishna river and it was in its holy waters that their ashes were immersed. On the downstream of the dam site, where my mother was cremated, a Hanuman Temple was built to cherish her memory.

With sanctioning of the Project in 1955 and laying of the foundation by the Prime Minister of India, the construction activity went into full swing From the investigation division, I was shifted to the Dam Construction Division. More Divisions and a Circle were sanctioned. Roads, Camps, lighting and other facilities for the staff were provided As the construction work proceeded, thousands of skilled and unskilled workmen were required. They were recruited from all parts of India and as many as 40,000 persons were at work at the peak period during the construction of the dam. Including the strength of workers employed on the canals, the number swelled to a hundred thousand. The construction of the dam was ahead of schedule. For want of adequate funds, the construction of canals could not keep pace with the dam and went behind the schedule and their cost became target of phenominal price hike.

It was on the 4th of August 1967 that the waters of the Nagarjunasagar Dam were ceremonially let out into the canals by Srimathi Indira Gandhi, Prime Minister of India.

Highest records of construction were achieved and the entire dam project was completed, under the able guidance of Dr. K. L. Rao, an eminent engineer of international repute. Dr. K. L. Rao guided the construction activity from the conception to the completion in the capacity as Member Designs, Central Water and Power Commission, and as the Union Minister for Irrigation and Power, Government of India. The Project was constructed entirely by the engineers of

India with no foreign experts. When I look back, I feel a sense of satisfaction in being associated with this colossal project right from inception to the completion and I feel gratified to have come in contact with eminent and dedicated engineers and workers who built this gigantic project. the completion of which has ushered in a better life for the people of Andhra Pradesh.

This book is not merely a narrative of the events and connected activities but also deals with the technical and salient features, the project management, design and plant layout, rates and cost and the problems encountered in the construction and their solutions

Dr. N Sanjiva Reddy, President of India honoured this book with his inspiring foreword and Dr. K. L Rao was pleased to give his valuable introduction to this volume My grateful thanks are due to Dr. N Sanjiva Reddy and Dr K. L. Rao. Magnificent contributions have been made to the construction of the project by outstanding engineers, Messrs. D. V. Rao, L Venkatakrishna Iyer, M. Jafer Ali, G. A. Narasimha Rao, A P. Ranganatha Swami, V. Suryanarayana, Major Rangaswami, A R. Chellani, P. T. Malla Reddy, K V. Sreenivasa Rao, T. C Krishna Rao, D. Balakrishna Rao, G. K. S Iyengar, V. Sree Hari, Satnarayan Singh and M Rahmatulla Khan and many other devoted engineers.

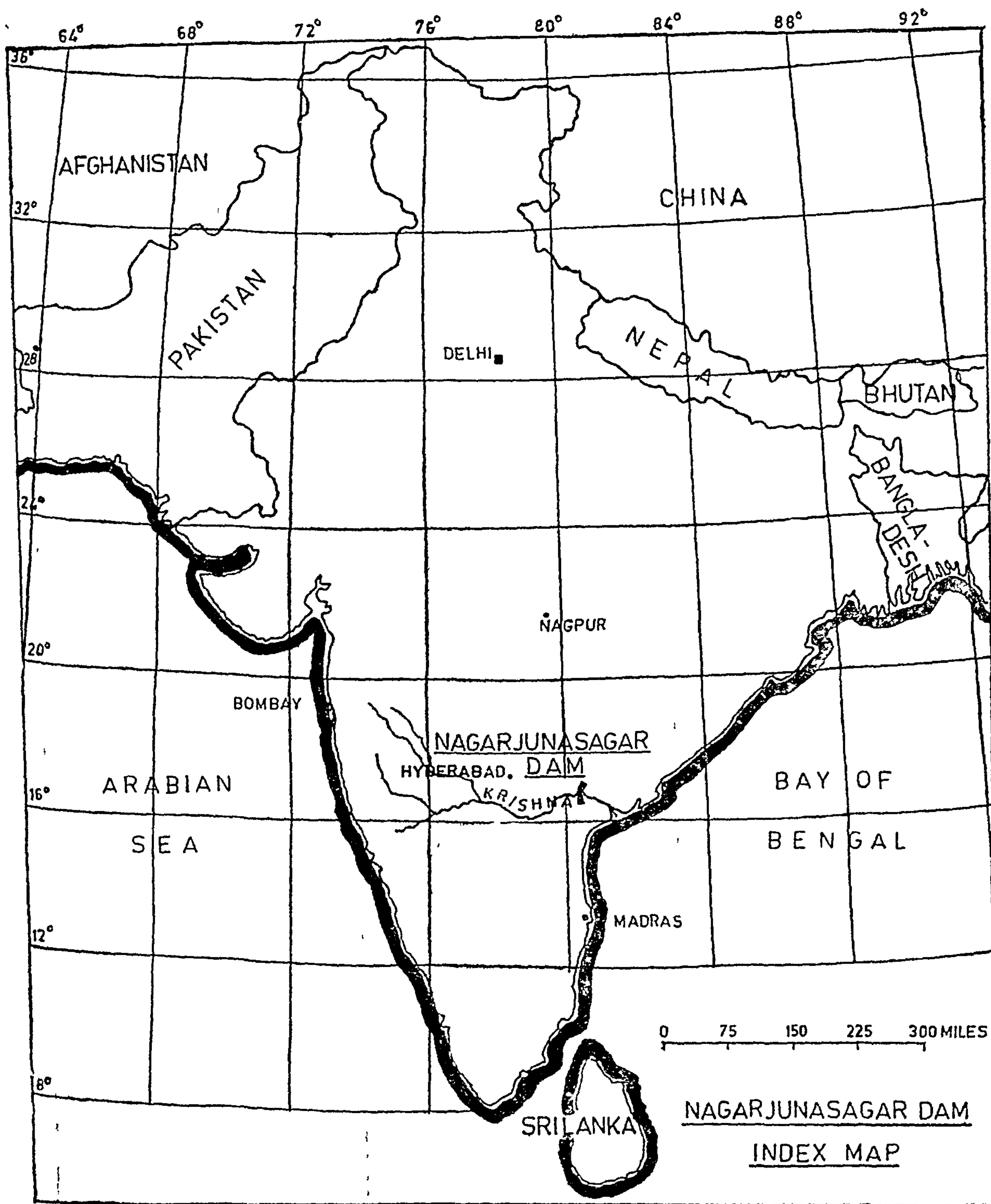
I have also to acknowledge with thanks the help given by Messrs. P. Vaman Rao, Rao Sarode, V. Sham Rao, S. K S. Iyengar and Mr. Sabir Hussain, who helped in going through the manuscript and for useful suggestions.

June 6, 1977 M. GOPAL RAO

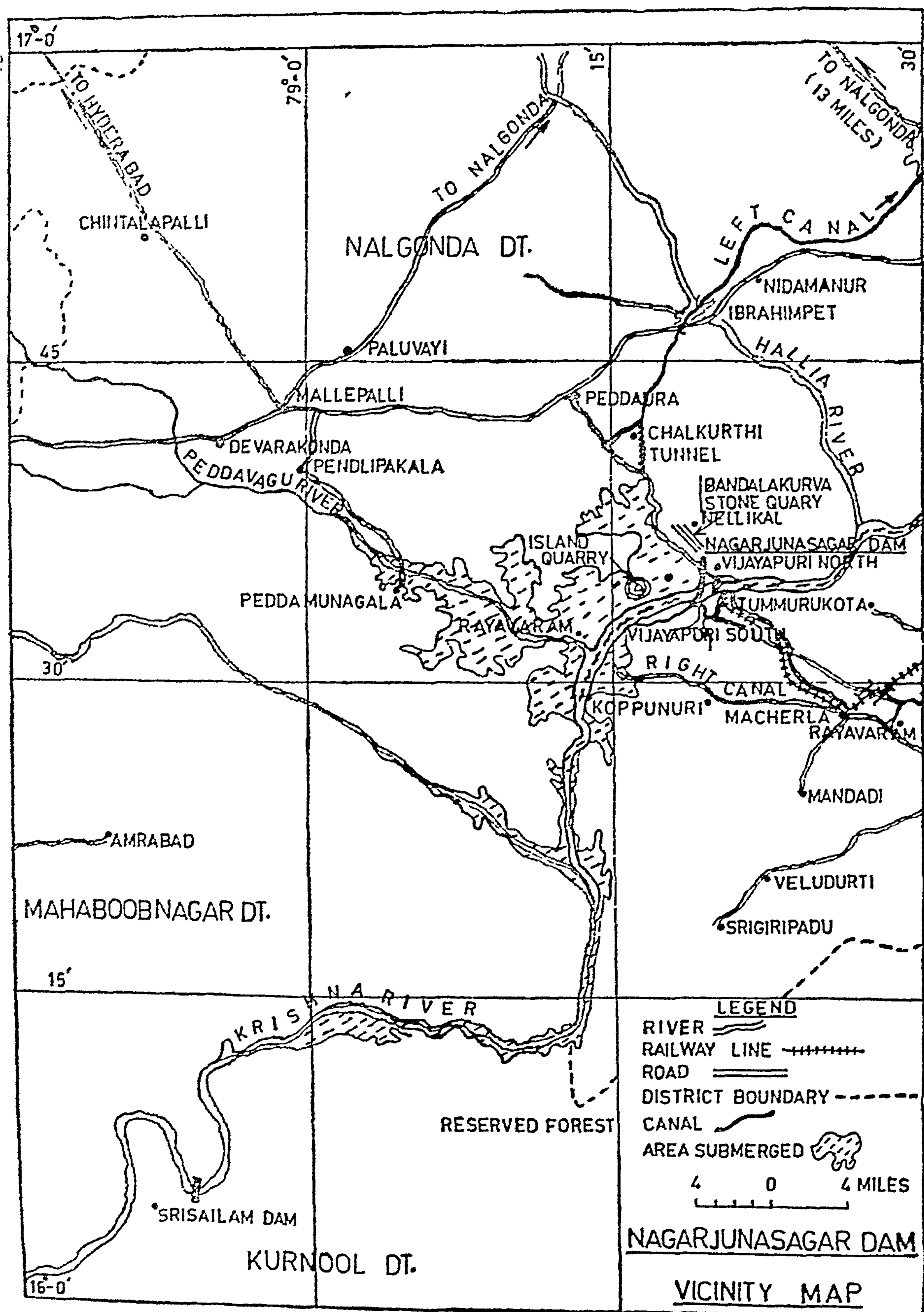
CONTENTS

INDEX OF PHOTOS

INDEX OF FIGURES



64°
68°
72°
76°
80°
84°
88°
92°
36°
32°
28°
24°
20°
16°
12°
8°
AFGHANISTAN
CHINA
PAKISTAN
NEPAL
DELHI
BHUTAN
BANGLA-DESH
NAGPUR
BOMBAY
NAGARJUNASAGAR DAM
HYDERABAD
KRISHNA
ARABIAN SEA
BAY OF BENGAL
MADRAS
0 75 150 225 300 MILES
SRILANKA
NAGARJUNASAGAR DAM
INDEX MAP


17°-0'
79°-0'
15'
30'
TO HYDERABAD
TO NALGONDA
TO NALGONDA (13 MILES)
CHINTALAPALLI
NALGONDA DT.
LEFT CANAL
NIDAMANUR
IBRAHIMPET
HALLIA RIVER
45'
PALUVAYI
MALLEPALLI
PEDDAURA
CHALKURTHI TUNNEL
DEVARAKONDA
PENDLIPAKALA
PEDDAVAGU RIVER
BANDALAKURVA STONE QUARY
YELLIKAL
ISLAND QUARRY
NAGARJUNASAGAR DAM
VIJAYAPURI NORTH
PEDDA MUNAGALA
TUMMURUKOTA
RAYAVARAM
VIJAYAPURI SOUTH
RIGHT CANAL
KOPPUNURI
MACHERLA
RAYAVARAM
MANDADI
AMRABAD
VELUDURTI
MAHABOOBNAGAR DT.
SRIGIRIPADU
15'
KRISHNA RIVER
LEGEND
RIVER
RAILWAY LINE
ROAD
DISTRICT BOUNDARY
CANAL
AREA SUBMERGED
4 0 4 MILES
RESERVED FOREST
SRISAILAM DAM
KURNOOL DT.
16°-0'
NAGARJUNASAGAR DAM
VICINITY MAP

CHAPTER I

KRISHNA RIVER

The Krishna, the sacred Krishnaveni, is one of the most illustrious and interesting rivers of India Hoary in its history and plentiful in its potential, it is the third largest river in India, after the Ganga and the Godavari. It rises from the fountain head of Gomukh (an image of a cow's mouth) in an ancient temple of God Mahadeva at the foot of a steep hill near Mahabaleshwar. It drains the Sahyadri, Balaghat, Mahadeve, Bababudan, Erramalai, Nallamalai and Parikonda hill ranges before entering the plains of the east coast on the last lap of its journey to the Bay of Bengal

Origin and Trail

1 2 On the Western Ghats in Maharashtra at an elevation of 1,336 metres near about 18° north latitude and 74° east longitude, the Krishna river rises. The Western Ghats form a great and continuous barrier for about 1,600 km. along the western side of the south Indian peninsula, roughly parallel to, and at only a short distance from, the Arabian Sea It is nowhere cut into by rivers. The eastern slopes of the Western Ghats, wherefrom the Krishna rises, receive the heaviest rainfall in India with the exception of the maximum rainfall regions in Assam. They run close and parallel to the coast of the Arabian Sea and down to the southern end of the peninsula Like most other parts of India the Krishna basin receives its maximum rainfall from the south-west monsoon. All the country east of these mountains drains into the Bay of Bengal and that to the west into the Arabian Sea The Krishna basin, with an area of 258,948 sq km , forms eight per cent of the total geographical area of India. Lying in the Deccan plateau, it covers large areas in the three States of Maharashtra, Karnataka, and Andhra Pradesh draining an area of 76,252 sq. km , 69,425 sq km and 113,271 sq km respectively. The total length of the river from source to outflow into the sea is about 1,400 km , of which 306 km are in Maharashtra, 482 km in Karnataka and 612 km. in Andhra Pradesh Together with its tributaries, the river drains about 708 km of the Western Ghats. The basin is roughly triangular in shape, with its base along the Western Ghats

1.3 From Mahabaleshwar, the Krishna runs southward in a rapid course for nearly 240 km , flowing through the districts of Satara. Belgaum

and Kaladgi Then its serpentine trail turns east and receives the tributaries of the Koyna, Yerla, Varuna and Dudhganga. Just near its confluence with the Dudhganga and about 305 km. from its source, the Krishna enters Karnataka At this point, the river comes down to an altitude of about 533 m. and emerges from the zone of heavy rainfall along and near the Western Ghats. For about 200 km after entering Karnataka there is no major contribution to the river Then, 35 km lower down, the Ghataprabha, and the Malaprabha, both rising from the Western Ghats, fall into the Krishna from the right. All these tributaries, like the main stream, have the characteristics of the Deccan plateau rivers. They run in deep courses, from which it is difficult to take off channels for irrigation on either bank In the rainy season, roughly lasting four months, June to September, they swell into brimming torrents, but during the remaining eight months of the year they shrink to mere threads of water After receiving the above tributaries, the Krishna drops in a rapid to the alluvial doabs of Sholapur and Raichur districts. The fall in elevation is as much as 90 m in about 50 km These rapids are known as the Jaldurg falls The Krishna meets its major tributary, the Bhima, which drains the districts of Poona, Ahmednagar and Sholapur and the fern of the doabs is formed at the confluence

The second most important tributary is the Tungabhadra which derives its name from its twin feeders, the Tunga and the Bhadra. The Tungabhadra drains the north and west of Karnataka and the districts of Bellary and Kurnool. After its junction with the Tungabhadra, the Krishna, flowing east, enters Andhra Pradesh

1.4 Flowing through the heart of Andhra Pradesh, the river becomes the rich repository of the great integrated cultural heritage of Maharashtrians, Kannadigas and Andhras from time immemorial. It has seen the rise and fall of empires and famous dynasties, chief among which were the Satavahana, Ikshvaku, Pallava, Châlukya, Kakatiya and Vijayanagara. On its banks equally throve a secularism of various religions *viz*, Hinduism, Buddhism and Jainism. Its waters reflect the soul of the culture and civilization of the Andhras, Kannadigas and Maharashtrians through the centuries.

1 5 A few miles east of Kurnool town, the Krishna flows through a hilly country and meets ranges of hills at Siddeshwaram and traverses the gorges for nearly 30 km., before entering the plains of the Coromandel coast at Pulichintala It then flows eastward and joins its important tributaries on its left flank, namely, the Dindi, the Peddavagu, the Halia, the Musi, the Paleru, the Muneru and the Kattaleru It is on the Musi that the famous and ancient city of Hyderabad, the capital of Andhra Pradesh, stands

1 6 The Krishna then enters the plains of the Coromandel coast at Pulichintala On both flanks of the river, there are outcrops of hills up to the town of Vijayawada, situated on its banks

1.7 Beyond Vijayawada, the alluvial deltaic plain stretches on both banks of the river After continuing its trail for a distance of 65 km , in a single channel of about 1 6 km width, it sends a branch to its left known as the Puligadda, that forms the island of Divi The main river continues for another 25 km , and breaks up into three branches, the Narasagunta Krishna, the Lankevanirichi Krishna and the Venisagara Krishna The bountiful Krishna, after flowing through the delta, finally empties itself into the Bay of Bengal on the east coast of Andhra Pradesh near the town of Machilipatnam

Rainfall and Characteristics of the River

1.8 The monsoon winds strike the west coast of the Indian peninsula from the west and south-west and strike the Western Ghats on the Sahyadri range, which present an almost uninterrupted barrier ranging from 610 m to 2,134 m in height The high rainfall zone along the Western Ghats forms the western boundary of the Krishna basin for a distance of about 708 km The annual rainfall varies from 1,016 mm to 3,048 mm in this reach East of the Western Ghats, the annual rainfall decreases rapidly until it is less than 600 mm along the line running approximately from Chitradurga to Sangli, to Poona and then to a point north and east of a line connecting Kurnool, Raichur, Bijapur and Ahmednagar. East of this, rainfall again gradually increases to about 900 mm in and around Guntur

1.9 January and February are almost entirely dry months in the Krishna basin The rainfall during these months is less than 15 mm. During the three months, March to May, the rainfall in most parts of the basin varies from 20 mm. to about 50 mm June to September are the four months of the south-west monsoon during which all parts of the basin receive their maximum rainfall Chiefly under the influence of the south-west monsoon from June to October, the Krishna brings down by far the greater quantity of water swelling into floods The highest flood as recorded at Vijayawada was 29,600 cumecs, a quantity more than twice as great as the maximum discharge of the Nile or the Cauvery After October, water in the river decreases rapidly till the end of January In summer, it does not overflow the Prakasam barrage at Vijayawada if the head sluices of the canal are open During these months the river dwindles down to a petty stream with a minimum discharge going as low as three cumecs A low dry-weather water level, a narrow and rocky bed, and a great rise in the flood level to as much

as 30 metres are some of the distinctive characteristics of the greater part of this mighty river above the Prakasam barrage at Vijayawada.

1.10 While studying the rainfall and characteristics of the Krishna basin, it would be interesting to compare them with those of the adjacent Godavari basin. The catchment area of the Krishna is 258,948 sq km. (1,00,000 sq. miles) while that of the Godavari is 314,000 sq km The length of the Krishna is 1,400 km. (870 miles), while that of the Godavari is 1,465 km. (910 miles) The configuration of the two basins is very different. The Krishna basin is roughly triangular with its base along the Western Ghats, the apex at Vijayawada and the Krishna itself forming the median All the major tributaries of the Krishna draining the base of the triangle fall into the river in the upper two-thirds in length. The Godavari basin is also roughly triangular in shape, but the main river itself runs practically along the base of the triangle Almost two-thirds of the catchment of the Godavari drains into the river in the lower one-third of its length. Due to this important difference in the characteristics of the river, till the middle point of its course, the Godavari carries only 20 per cent of its water while the Krishna carries more than 80 per cent of its flow even at its middle reach (See Fig. 1.)

From the isohytes of the Krishna basin the average annual yield of the Krishna has been worked out to 2,217 T.M. C.ft The yields of various sub-basins are given below :

(One T M C ft = 28 3 mil Cum)

Name of Sub-basin	Direct catchment area (square miles)	Weighted average rainfall		Rough estimate of average annual yield		
		Annual (inches)	June September (inches)	T M C ft.	M. Cft per Sq. mile of catchment	Inches of depth
1. Upper Krishna	6,939	59.4	50 6	550	79.3	34 1
2. Middle Krishna	6,779	22 2	14 4	35	5.2	2 2
3. Ghataprabha	3,409	36 3	26 4	190	55 7	24.0
4. Malaprabha	4,459	26 6	17.0	70	15.7	6.8
5. Upper Bhima	17,786	26 6	20.7	400	22.5	9.7
6 Lower Bhima	9,478	26.0	19 6	55	5.8	2.5
7. Lower Krishna	13,948	28.4	20.0	210	15.1	6 5
8 Tungabhadra	18,465	34 8	24 5	520	28.2	12.1
9 Vedavati	9,108	22 4	11.3	50	5 5	2.4
10 Musi	4,329	29 5	21 5	50	11.6	5.0
11. Paleru	1,260	31 9	23 8	17	13.5	5.8
12. Muneru	4,019	37 6	28 5	70	17 4	7 5
Total				2,217		

Another point of interest is that the total area irrigated in the drought area lying in the Krishna basin is only next to that of the Ganga basin. The area irrigated in the drought area of the Ganga basin is 3,526,000 hectares, while that of the Krishna basin is 1,602,000 hectares

THE TRIBUTARIES

The Koyna

1.11 The Koyna is the first and the most important tributary of the Krishna Rising in the Western Ghats near Mahabaleshwar close to the Krishna, the Koyna flows between the table-land of Mahabaleshwar and Pratapgarh in a southerly direction for about 65 km. and then takes a L-bend to flow east for about 65 km before meeting the Krishna at Karad The Koyna dam was constructed across this tributary, diverting the east flowing waters to the west of the ghats for developing power

The Yerla

1.12 The Yerla rises in the Mahadeve hills in Khatave taluk of North Satara and flows in plain country till it joins the Krishna at Baramahal, after traversing in all a length of about 115 km in dry tracts.

The Panchganga

1.13 The Kasari and the Bhogavati, both originating in the Western Ghats, together form the Panchaganga It flows from west to east and joins the main river near Kurudwadi Its length is about 69 km.

The Varuna

1 14 The Varuna rises in the Western Ghats and runs partly through steep hilly country to a total length of 150 km. It has the Kardi, the Bhogi, the Kansa, the Yellapur, the Morna and the Khadari as its smaller tributaries

The Dudhganga

1.15 The Dudhganga rises in the Sahyadri mountains in Ratnagiri taluk of Kolhapur district at an altitude of 918 m After flowing for 72 km. across hilly and rugged terrain, it crosses Maharashtra into Karnataka and flows for 52 km in Karnataka before joining the Krishna at an elevation of about 536 m near the village of Yadur in Belgaum district The catchment of the Krishna at the confluence of the Dudhganga lies mostly in Maharashtra extending over 17,971 sq km. Only a short length of the Dudhganga is in Karnataka The length of the sub-basin along the Western Ghats is 225 km and the maximum width from west to east is about 112 km.

The Ghataprabha

1.16 The Ghataprabha rises in the Sahyadri hill range at an altitude of 884 m. near Ghokul, 48 km west of Belgaum town and flows easterly through the districts of Belgaum and Bijapur. It has three main tributaries, the Hiranyakeshi, the Tamraparni and the Markandeya. The length of the river is 284 km. and it runs partly through hilly terrain. It joins the Krishna at Kudlisangam at an elevation of 500 m. The total catchment area of the Ghataprabha and its tributaries is 8,829 sq.km. in Maharashtra and Karnataka. The principal source of yield of this river is an area of 4,000 sq km. of the Western Ghats, 64 km. in width to the east of these hills. Within this area the annual rainfall decreases from about 4,048 mm to about 1,016 mm

The Malaprabha

1.17 The Malaprabha rises in the Western Ghats at an altitude of 793 m., about 16 km. west of Belgaum district of Karnataka. It joins the Krishna at an elevation of about 488 m. The length of the river is about 306 km. and its total catchment area along with that of its tributaries is 11,549 sq.km. Its principal source of supply is only about 32 km. of the Western Ghats and a small area east of it. Its principal tributaries are the Bennihalla, the Hirehalla, and the Tasnadi, all of which drain an area of relatively low rainfall.

The Bhima

1.18 The Bhima rises in the Western Ghats at an altitude of about 945 m at a place called Bhimashanker in Poona district and flows south-east through Maharashtra and Karnataka. It has a total length of 861 km. and falls into the Krishna about 26 km. north of Raichur at an altitude of 343 m. The Mula, the Mutha, the Ghod, the Man, the Nira, the Sina and the Kagna are its main tributaries. For the last 299 km. of its course, the Bhima flows in Karnataka. No major tributary falls into the Bhima in this reach. The Bhima has a total drainage area of 76,614 sq.km. Its principal source of supply is a length of about 161 km of the Western Ghats.

The Tungabhadra

1.19 From its confluence with the Dudhganga to its confluence with the Bhima, excluding the basins of the Ghataprabha and the Malaprabha, the Krishna has a catchment area of 17,558 sq km. and lies mostly in Karnataka. In this region the Krishna drops from 610 m. to 305 m in elevation.

The Tungabhadra, an important tributary of the Krishna, is formed north of Shimoga at an elevation of about 610 m by the union of the

twin rivers, the Tunga and the Bhadra, which rise together in the Western Ghats at Gangamula at an elevation of 1,196 m. The united river, the Tungabhadra, flows for about 531 km in a generally north-easterly direction through Karnataka and Andhra Pradesh and joins the Krishna beyond Kurnool at an elevation of 264 m. The Varada and the Vedavati, also known as the Hagari in its lower reaches, are its two important tributaries. The total catchment area of the Tungabhadra is 71,417 sq km. Like the Bhima, it drains about 206 km length of the Western Ghats.

In addition to the multi-purpose major dam built across the Tungabhadra in 1955, anicuts were built at Sunkesala and at Rajula Banda for irrigation. The Sunkesala anicut was planned and constructed by the Rayas of Vijayanagar in the 1550s. The Rajulabanda anicut was built in 1955.

The Dindi

1.20 The Dindi rises in the Purasampally State forest of Mahabubnagar district and flows south-east to join the Krishna near Empalapadu village, which is now submerged in the lake of Nagarjunasagar.

A storage reservoir for irrigation was built in 1940 across the Dindi river with an ogee masonry spillway, supplemented by a high co-efficient weir.

The Okachettivagu

1.21 The Okachettivagu rises in Kodangal taluk and flows south to join the Krishna near Ramannapet in Atmakur taluk. The basin is more or less plain.

The Halia

1.22 The Halia river rises in Ibrahimpatnam taluk of Hyderabad district and flows south-east for about 115 km before joining the Krishna near Chatial.

The Peddavagu

1.23 The Peddavagu rises in the hills of Ramanandha State forest and flows south-east for about 110 km before joining the Krishna at Rayavaram, now submerged in the Nagarjunasagar lake. This river flows through the plains. Across this river, an irrigation storage reservoir was built near Pendlipakala in the 1940s.

The Musi

1.24 The Musi, with a drainage area of 11,212 sq km rises in Vikarabad taluk of Medak district at an altitude of about 661 m. and joins the Krishna near Wazirabad in Nalgonda district, at an elevation of

about 61 m. after traversing a length of about 268 km. It flows through Hyderabad city and runs mostly west to east until it is joined by the Aleru. The total catchment area is 11,212 sq.km. lying wholly in Andhra Pradesh It traverses a low rainfall area with an annual rainfall of 635 mm. to 813 mm.

The masonry dams of Osmansagar and Himayatsagar were built in this valley in the 1920s for flood control and water supply to Hyderabad city Later in 1958, the Musi dam was built lower down near Suryapet for irrigation.

The Paleru

1.25 The Paleru is another important tributary of the Krishna and has a catchment area of 3,263 sq.km. lying wholly in Andhra Pradesh. It has a greater run-off than the Musi. A storage reservoir, the Palair reservoir with automatic falling gates, was built across this river for irrigation in the 1940s. The left canal of Nagarjunasagar (the Lal Bahadur Canal) passes through this reservoir.

The Munneru

1.26 The Munneru, with a catchment area of 10,409 sq.km. is the last important tributary of the Krishna before it joins the sea. It rises in the famous Pakhal lake near Narasampet village (Warangal district) and flows south for about 182 km before joining the Krishna. On its way, it receives several tributaries from both sides.

Early Utilisation of Krishna Waters

1.27 The Krishna basin was utilised for irrigation from the earliest times Tanks were built in most of the villages from time to time by progressive rulers or through the co-operative efforts of the people. There are nearly 27,000 small tanks and diversion weirs on the river system.

1.28 The earliest irrigation work in the basin dates back to 1,200 A.D when the Ramappa tank was built by the Kakatiya kings of Warangal The tank is functioning to the present day. It was in 1800 A.D. that the outstanding masonry arch dam, the Meer Allum dam, was built for water supply to the city of Hyderabad.

1.29 The most important irrigation work in the Krishna delta canal system was envisaged by the eminent engineer, Sir Arthur Cotton The system was constructed in 1855 by putting up an anicut across the Krishna near Vijayawada where the width of the river is 1.19 km. This project, with an irrigation potential of 556,400 hectares, was built at a cost of Rs. 74.09 million.

1.30 In 1863, Sir Arthur Cotton visualised another anicut across the Tungabhadra, a major tributary of the Krishna, at Sunkesala, for diverting the waters to the famine stricken Kurnool and Cuddapah districts From the anicut, the canal takes off on the right bank and irrigates 39,510 hectares The project was completed in 1866 at a cost of Rs 74 47 million

1.31 The Nira canal project, constructed in 1885-86, consists of a dam 1,625 m long, and 49.7 m high across the Yelvandi at Bhatghar (Poona district of Maharashtra State) a 693 m long masonry pick-up weir on the Nira at Vir and a canal system on either bank to irrigate an area of 82,739 hectares. The project cost Rs. 71.97 million

Present Utilisation of Krishna Waters

1 32 Before studying the Nagarjunasagar project in detail, it will be of interest to provide a brief historical background to the important irrigation and power projects built in the Krishna basin. They are as follows .

MAHARASHTRA

Radhanagari Project

1.33 The Radhanagari project was taken up in 1949 by the erstwhile Kolhapur State, which was later merged in Maharashtra The project consists of a masonry dam 1,143 m long and 38 4 m. high across the Bhogawati in the Panchganga valley of the Krishna basin The total irrigated area is 9,308 hectares The project which costs Rs 21·8 million was completed in 1967

Ghod Project

1.34 The Ghod Project comprises the construction of an earthen dam 2,852 m long and 29 6 m. high across the Ghod near the village of Chinchi (in Sirur taluk of Poona district in Maharashtra State) Two canals take off, one from each bank The right bank canal is 33 5 km and the left bank canal 86 5 km long The total area irrigated by the project is 24,615 hectares The project costing Rs 55 6 million, was started in 1954 and completed in 1966

1 35 The first stage of the Khadakwasala project consists of an earth dam 823 m long and 58 m high across the Ambi at Panshet, 27 km. upstream of the existing Khadakwasala dam in the Poona district of Maharashtra State It provides for the strengthening of the existing Khadakwasala dam across the Mutha 17.7 km. from Poona The main canal with a length of 127 km irrigates 22,298 hectares Work on the

project, costing Rs. 167 million was started in 1957 and completed in 1973.

Vir Project

1.36 The Vir dam project consists of a composite dam 3,607 m. in length, with a height of 35 m. built across the Nira near Vir village, about 16 km east of Shirwal in the Poona district of Maharashtra State. The reservoir feeds the existing Nira right and left main canals to irrigate 26,710 hectares. The work on the project costing Rs. 541 million was started in 1957 and completed by 1972.

Koyna Project

1 37 The Koyna hydro-electric project is an important one. It diverts Koyna waters outside the Krishna basin into the Arabian Sea. The project consists of a dam across the Koyna at Deshmukhwadi near Helwak (in Satara district of Maharashtra State). An underground power station has been constructed at Pophili, below the Western Ghats. The project was taken up in three stages, the installed capacity in the first, second and third stages being 240 M.W. 300 M.W. and 320 M.W. respectively The three stages cost Rs. 382 8 million, Rs .181.6 million, and Rs 380.0 million respectively. The first two stages were completed in 1963 and 1968 respectively and the third in 1975.

Bhima Project

1 38 The Bhima project consists of two dams : one rockfill dam across the Pawna, a tributary of the Bhima and a masonry dam across the Bhima The Pawna dam is near Phagna in Poona district of Maharashtra. The Bhima dam is near Vijaire (in Madha taluk, Sholapur district) The project was taken up in 1964 and is to be completed in 1978.

Krishna Project

1.39 The Krishna project consists of three dams, Dhom, Borkhal and Kanhar, all earth dams in the main gorge and masonry spillway. The dams are named after the villages where they are situated in the district of Satara. The Dhom and Borkhal dams are across the Krishna and the Kanhar dam across the Venna. The project was taken up in 1969 and is expected to be completed in 1978.

KARNATAKA

Bhadra Project

1.40 The Bhadra project comprises a masonry dam with earth flanks of a total length of 440.5 m and a maximum height of 71.6 m.

across the Bhadra near Lakkavalli, about 22 5 km from Bhadravati railway station. The reservoir has a gross storage of 2,023 m cu.m., out of which the live storage is 1,789 m cu m The main canal is 176.6 km. long and will irrigate a total area of 99.015 hectares. The work on the project costing Rs 350 million was started in 1947 and completed in 1973

Ghataprabha Project

1.41 The first stage of the Ghataprabha project comprises a weir across the Ghataprabha near Dhupdal village in the district of Belgaum The weir is 2,084 m long and 8 95 m high The main canal is 70 8 km. long and irrigates 74,060 hectares Work on the first stage costing Rs 69 25 million was started in 1949 and completed in 1971.

1.42 The second stage consists of a composite dam across the Ghataprabha near Hidkal village, about 19 km upstream of the Dhupal weir. The dam will be 8,841 m long and 50 m. high The stage-I main canal has been extended by 43.45 km to irrigate an extra area of 46,540 hectares. Work on the project costing Rs 485 3 million was started in 1956 and completed by 1976.

Upper Krishna Project

1 43 The Upper Krishna project consists of two dams across the Krishna, one at Alamatte village in Bagewadi taluk and the other at Siddapur in Muddebihal taluk of Bijapur district. They are masonry gravity structures with a height of 34.76 m and 23 63 m. respectively.
The site of the Siddapur dam was selected below the confluence of the Malaprabha with the Krishna at Narayanpur Its construction was started in 1964 and about 50 per cent of the work was done by 1974. This project is expected to be completed by 1978 The construction of the dam at Alamatte, proposed at the confluence of the Ghataprabha, was taken up in 1975

Tungabhadra Project

1.44 The Tungabhadra project is a scheme jointly taken up by the erstwhile Hyderabad and Madras States The States concerned at present are Andhra Pradesh and Karnataka The project consists of a dam across the Tungabhadra at Mallapur village in Bellary district, about 4 8 km from Hospet in Karnataka The dam is of the straight gravity masonry type, 2,441 m long It has a maximum height of 49.39 m The reservoir has a gross storage of 3,767 m cu m Two canals take off, one from each bank. The total length of the right bank canal is 349 km and it serves both Karnataka and Andhra Pradesh The left bank canal, which is 227 km. long, serves only Karnataka The areas irrigated by the right bank canal are 37.374 hectares in Karnataka and

60,247 hectares in Andhra Pradesh. The left bank canal irrigates an area of 234,726 hectares, which is entirely in Karnataka. The work on the dam was started in 1945 and completed in 1956. The right bank canal was completed in 1955, and the left bank canal in 1963. Another high level canal of 113 cumec capacity is under construction on the right bank for irrigation in Karnataka and Andhra States. The project also generates power in two power houses, on the right and left banks. The ultimate installed capacities of these two power houses are 72 M.W. and 54 M.W. respectively. The total cost of the project was Rs. 1,053.9 million.

Rajolibanda Diversion Project

1 45 The Rajolibanda diversion project is a joint scheme of Karnataka and Andhra Pradesh. It consists of a masonry anicut 820 m. long and 9.4 m. high, across the Tungabhadra at Rajolibanda, and the left canal 143 km. long in Karnataka and Andhra Pradesh, to irrigate a total area of 37,990 hectares The cost of the project was Rs. 38.3 million Work was started during 1953 and completed in 1973.

ANDHRA PRADESH

Srisailam Dam

1 46 The Srisailam dam is being built across the Krishna near Srisailam town in Kurnool district in Andhra Pradesh. The dam is being built in masonry with a height of 143 3 m. above the deepest foundation level. The reservoir has a gross storage of 8,716 m.cu.m. The Srisailam hydro-station will have an installed capacity of 770 M.W. in the first stage and one million K.W. of power in the ultimate stage The project was started in 1964 and will be completed by 1980. It is also proposed to construct a right bank canal taking off from the foreshore of the reservoir for irrigating arid lands in Cuddapah and Chittoor districts besides water supply to Madras City.

Jurala Project

1.47 Consequent to the reorganisation of States, Karnataka restricted the scope of the Upper Krishna projects, so as to benefit the areas lying only in Karnataka State. For utilising 17.87 T.M Cft. (506.1 m.cu.m.), the Andhra Pradesh share of Krishna waters, a dam has been proposed across the Krishna at Jurala, six km. north of Gadwal in Mahboobnagar district. The scheme has been investigated and is proposed with a storage capacity of 12 T M Cft. (340 m.cu m) for irrigation of 105,000 acres (42,500 hectares) under the north and south canals in the taluks of Gadwal, Alampur, Atmakur, Wanparti and Kolapur. The project is estimated to cost Rs 500 million.

Nagarjunasagar Project

1.48 The Nagarjunasagar project is situated 96 km. down below Srisailam. It consists of the largest masonry structure in the world for irrigating 1 4 million hectares and with an installed capacity of half a million K.W. of power. It is fully described in this volume The dam was started in 1956 and completed in 1970.

Prakasam Barrage

1.49 The Prakasam Barrage was built 177 km below Nagarjunasagar dam. It has been named in memory of the great Chief Minister of Andhra, Mr T. Prakasam It was built in 1956, replacing an old anicut built by Sir Arthur Cotton in 1852 which had deteriorated There is an irrigation of 0 48 million hectares under this barrage

Pulichintala Dam

1.50 Between Nagarjunasagar dam and the Prakasam Barrage, the Pulichintala dam has been proposed across the Krishna This will be a terminal reservoir for arresting the flows in excess of dependable flows in good years This reservoir will irrigate additional lands and generate 50 M W of power at 0 5 load factor

Sharing of Waters of the Krishna

1 51 From 1947, when India became independent, there was all-round activity in planning for intensive development of water resources all over the country both at the State and national levels Every State proposed important schemes for utilization of the waters of its rivers

On June 28 and 29, 1951 a conference of the Planning Commission was held in New Delhi for the utilization of Krishna waters with the representatives of the States of Bombay, Madras, Hyderabad and Mysore. The Central Water and Power Commission prepared a technical note on the utilization of supplies in the Krishna valley on the basis of the information supplied by the Governments of the States The memorandum of agreement apparently had settled the conflicting claims of the riparian States with regard to the supply of the Krishna river system for 25 years.

1 52 With the Andhra State Act of 1953, and the States Re-organisation Act of 1956, extensive territorial changes took place The new States of Bombay, Mysore and Andhra Pradesh became the riparian States in place of the old States of Bombay, Hyderabad, Mysore and Madras In view of these vast territorial changes, the Central Water and Power Commission drew up a scheme for reallocation of the Krishna waters. This scheme was not accepted by the States An inter-State conference

convened in September 1960 could bring about no settlement. The legal validity of the 1951 agreement stood severely challenged and the State Governments raised objections to the clearance of new projects by the Government of India, on the basis of the 1951 agreement apportionment of the waters of the Krishna

1.53 For the purposes of the 1951 agreement, the dependable annual flow of the Krishna was accepted as 1715 T.M.C. (48,300 m cu.m.). The allocations for the existing utilization and for a few projects under construction were as follows :

State		T.M.C.	m.cu.m.
Bombay	.	176.00	5000
Hyderabad	..	180.00	5040
Mysore	..	98.50	2760
Madras	..	290.00	8210
Total	..	744.50	21010

Out of the balance flow after the above existing allocations, new allocations were made as follows :

State		T.M.C.	m.cu.m.
Bombay	..	240	6800
Hyderabad	..	280	7940
Mysore	.	10	300
Madras	..	470	13310
Total	..	1000	28350

The balance flow in excess of the 1000 T.M C. was allotted as follows :

Bombay	..	30	per cent.
Hyderabad	..	30	per cent.
Mysore	..	1	per cent.
Madras	..	39	per cent.
Total	.	100	per cent.

1.54 It was stated by the Government of India that as a result of further engineering scrutiny, the allocation to Mysore might be increased by one per cent and that the increase will come out of the Madras share It was provided that the allocation would be reviewed after 25 years.

1 55 Consequent on the all-round dissatisfaction about the 1951 allocation and the subsequent reviews, the Central Government in May 1961 appointed the Krishna-Godavari Commission headed by Mr Gulhati, an eminent engineer. In August 1962 the Commission submitted its report The conclusion of the Commission was that without further data it was not possible to determine the dependable flow accurately. It was also the finding of the Commission that with the available supply in the Krishna which is inadequate, the demands of all the projects of the State Governments could not be met The other important proposals put forward by the commission were diversion of Godavari water into the Krishna and carrying out regular gaugings at key sites on the river system to assess the correct flow of the river

1 56 On March 23, 1963, the Union Minister for Irrigation and Power, Mr. Hafiz Mohammed Ibrahim, stated that, according to expert legal opinion, the 1951 agreement had become void if not fully, at least partially. The Minister further stated that new projects should not be held up until a settlement of the controversy over the allocation of Krishna waters.

1 57 As per his decision the flow of the Krishna was assessed at 50,940 m cu.m at 75 per cent dependability , and Andhra Pradesh, Mysore and Maharashtra were allotted 22,640 m cu m 16,980 m cu m and 11,320 m cu.m. respectively This decision was considered tentative, as the available data were not sufficient for a correct assessment of the yield and, therefore, systematic and scientific data were to be collected Therefore it was ordered that the actual river flows should be gauged and the allocation reviewed by 1976. Accordingly, to assess the water flow scientifically, 38 gauge stations were set up along the river These statistics came into existence from 1955. The most important factor was that the water flow in the various catchment areas had to be estimated separately and accurately This was particularly necessary because a project planned in a particular catchment area for utilisation of the supplies either in excess or short of the real flow would mean a national loss.

1.58 Though the decision given by Mr. Hafiz Mohammed Ibrahim was an interim allocation in June 1963, the Maharashtra Government requested the Government of India to refer the dispute to a tribunal. A similar request was made by the Mysore Government as early as January, 1962.

1.59 Even after taking action on the recommendations of the Gulhati Commission and conducting the detailed investigations concerned at the technical level with regard to diversion of Godavari waters into the Krishna and carrying out model experiments at research stations to reconstruct the data of the yearly flow at Vijayawada, the problems of quantitative assessment of the dependable yield of the Krishna remained unsolved as the reliability of the model experiments and the accuracy of the reconstructed flow were disputed by the States Any settlement was out of sight in spite of negotiations and conducting several inter-State conferences, and with fresh references from the State Governments for early constitution of a tribunal. The Government of India, therefore, appointed a tribunal in April 1969 headed by Mr R. S. Bachawat, a Judge of the Supreme Court of India, and with Mr Shamsher Bahadur, a Judge of the Haryana High Court and Mr. D M. Bhandari, Chief Justice of Rajasthan High Court, as members.

1 60 The tribunal, after hearing the contentions and arguments of all the riparian States, passed the final order regarding the sharing of Krishna waters in December 1974. The tribunal determined that for the purposes of this case the 75 per cent dependable flow of the Krishna up to Vijayawada is 2060 T M C (58360 m cu.m) The following allocation was ordered

Maharashtra .	565	T M.C.	16,000	m.cu.m
Karnataka	695	,,	19,700	,,
Andhra Pradesh	800	,,	22,660	,,
Total .	2060	,,	58,360	,,

In addition to allotting 800 T.M C to Andhra Pradesh, the tribunal held that the State will be at liberty to use in any water year the residual supplies that may be flowing in the Krishna, but that thereby it shall not acquire any right to use in any water year in whatsoever excess of the quantity specified

1.61 The tribunal further ordered that at any time after May 31, 2000 A D. its orders may be reviewed or revised by a competent authority or tribunal, but that such review or revision shall not as far as possible dispute any utilization that may have been undertaken by any State within the limits of the allocation made to it under the tribunal's orders The tribunal also made it clear that nothing in its order shall prevent alteration, amendment or modification of all or any of its orders by agreement between the parties or by legislation by Parliament

After the award by the Krishna tribunal, the States of Karnataka, Maharashtra and Andhra Pradesh and the Government of India filed four separate references before the tribunal itself, seeking clarification on certain points. After hearing the parties, the tribunal gave its final orders in 1976 slightly modifying the allocations to Karnataka and Maharashtra As per the final orders, the quantities allocated are as follows .—

Maharashtra	560 T.M.C
Karnataka	700 T.M.C
Andhra Pradesh	800 T M C
Total	2060 T M C

The decision of the tribunal thus brought finality to the allocation of Krishna waters which had been a matter of controversy for over a quarter of a century.

Subsequently at the instance of the then Prime Minister Mrs Indira Gandhi, the party States agreed to spare five T M C each out of their allotted quota for drinking water purposes to Madras City This was an arrangement outside the scope of the award of the tribunal and was purely on humanitarian grounds by the three States

Places of Interest and Shrines in the Krishna Valley

1.62 The Krishna and its beautiful valley have played an important role in the life of Maharashtra, Karnataka and Andhra Pradesh These States are well known for their cultural and historic heritage.

Several civilizations rose and fell in this valley. The remains can be seen in Hampi (near Hospet) in Karnataka and Nagarjunakonda (near Vijayapuri) in Andhra Pradesh Hampi was the capital of the Vijayanagar empire Nagarjunakonda which dates back to the first century A D was the capital of the Ikshvakus Gulbarga and Golkonda were the capitals of the Bahmani and Kutub Shahi kingdoms respectively

There are several important temples and mosques on the banks of the Krishna and in its basin in the three States. The most important are Mahabaleshwar, Pandharpur, Sringeri, the mosque of Gulbarga, Narsimha Parvata, Shimoga, Baba Budangiri, Hampi, Golgumbad in Bijapur, Srisailam, Vedagiri, Amaravati, Mangalagiri and Vijayawada These places are described below .

MAHARASHTRA

Mahabaleshwar

1 63 The Krishna takes its origin near Mahabaleshwar, which is a sacred place for Hindus Besides being a tourist centre it is a summer resort

Bhimashankar

1.64 The Bhima river originates in Bhimashankar. The temple of Mahadeva is one of the Dwadasa linga shrines.

Alandi

1.65 Alandi is on the Poona-Nasik road and has a fort and a temple of Sant Gnyaneshwar, the famous author of 'Gnyaneshwari,' a commentary on the 'Gita'* in Marathi.

Junnar, Shivner, Karli, Bedsa Caves

1.66 The excavated Buddhist caves of Junnar and Shivner, situated about 90 km. north-west of Poona on the right bank of the Kudli, date to the first to the fourth century A.D. The Karli and Bedsa caves are very important artistically.

Poona

1.67 Besides having the remains of Shivaji's times and Sinhgadh fort in its vicinity, Poona has a beautiful temple of Goddess Parvathi located on the top of a hill towards south. Poona is also the seat of several State and Central Government offices.

The Khadakwasla dam on the Mula Mutha stream, about 13 km west of Poona, where the Central Water and Power Research Station is located, the Lloyd Dam across the Nira about 33 km south of Poona, regulating the large depression of Bhatgar lake, and a series of hydel schemes dotted in picturesque surroundings across small tributaries of the Bhima are some places of engineering interest worth visting near Poona

Ahmednagar

1.68 The Chand fort in Ahmednagar about 120 km north-east of Poona on the bank of the Sina is a place worth visiting

Harischandragadh

1 69 Harishchandragadh fort is at the apex of the watershed of the Bhima and the Godavari river systems.

Jamkhed

1.70 Seventy-two km. south-east of Ahmednagar, there is a waterfall 33 m. high near Jamkhed which, in the rainy season, is a scene well worth a visit

Sholapur

1.71 Sholapur fort, 264 km south-east of Poona, belongs to the 14th century. It is a place of historic importance.

*The ancient Sanskrit scripture, the Bhagavat Gita

Pandharpur

1.72 Pandharpur, the city of 'Pandhari Vithoba', is 64 km. west of Sholapur. The chief temple of Pandharpur is the 'Pandhari Kshetra' of the 16th century

Karmala

1.73 One of the largest forts in Deccan, extending over 0.65 sq km is located in Karmala.

Shival

1 74 Shival 24 km. north of Wai, has a group of fifteen early Buddhist caves

Tathavadi

1.75 Tathavadi or Santoshghad is a hill fort, triangular in shape, built by Shivaji.

Naldurg and Tuljapur

1.76 Naldurg and Tuljapur in Osmanabad district are famous for a fort and a temple of Goddess Bhavani respectively.

KARNATAKA

Sringeri

1.77 On the left bank of the Tunga, Sringeri is the centre of Advaita Philosophy. Sankara founded one of his spiritual thrones at this place It has been occupied till today by a succession of great seers

Narasimha Parvata

1 78 Narasimha Parvata is about five km distant from a place called Kiggs near Sringeri Right on the top of the hill there are several natural depressions, which, when put together, look like the God Ugra Narasimha, tearing Hiranyakashyapa to pieces. Halfway up the hill, on a diversion to the west there is said to be a Kala Bhairava image of dark granite, which was buried in a landslide

Hariharapura

1.79 Hariharapura on the Tarikere-Mangalore road, is famous for the car festivals of Lord Narasimha and Goddess Sarada that take place in the month of Vaisakha every year

Shimoga

1.80 Shimoga derives its name from Shiva-Mukha, the face of Lord Shiva and is famous for its Hanuman and the Kodandarama temples.

Kudli

1.81 Kudli is the confluence point of the Tunga and the Bhadra. At the northern end of the village are two temples of the Hoysala period. the Rameshwara and the Narasimha.

Chorana Yadeshalli

1.82 Chorana Yadeshalli contains a temple of Lord Shiva, built of pot-stone.

Thirthahalli

1.83 Thirthahalli has a number of sacred bathing places on the banks of the Tunga.

Tunga Anicut

1.84 Near Sacrebyle, the Tunga anicut is a place of tourist interest.

Baba Budangiri

1.85 Baba Budangiri is a well known place of pilgrimage of Hindus and Muslims. Places of importance on this hill are Dattatreya Pitha, a ruined fortress, retreat for penance.

Bhadravati

1.86 Bhadravati is the seat of Bhadravati Iron Works, now renamed Visvesvaraya Iron Works. In the centre of the old town on the right bank of the river Bhadra on the top of a rising ground is a temple of Lakshminarasimha.

Lakkavalli Dam

1.87 With a large reservoir, Lakkavalli dam site is a place of tourist interest.

Vanivilas Sagar

1.88 The waters of the Vedavati have been impounded in Vanivilas Sagar and with magnificent scenery all around it is a place of tourist interest.

Tungabhadra Dam

1.89 Tungabhadra Dam is one of the important masonry dams in the country. It draws innumerable tourists all round the year.

Hampi

1.90 Hampi, called the 'Pompei of India', was the capital of the Vijayanagara empire. It contains the Vijaya Vithal temple, the carved stone chariot and large images of Ugra Narasimha and Ganesha (from which the geological term 'gneiss' is derived) In ancient times this particular stone was used to carve images of Ganesha (the elephant faced God) as well as of other deities, mostly Ganesha—hence the German word 'gneiss'.

Bellary

1.91 Bellary fort is built on a level plane skirting two hills about a mile and half in circumference.

Badami

1.92 The cave temples of Badami of thick sandstone date back to the fifth century A D. They are known for their carvings of images of deities and designs.

Pattadkal

1.93 Twenty kms from Badami, Pattadkal contains fine temples which date back to the seventh and eighth centuries.

Gokak Falls

1.94 About 72 km north-east of Belgaum, the Ghataprabha takes a mighty leap of 52 m over a sandstone cliff in a picturesque gorge to form the Gokak Falls.

Gulbarga

1.95 The fort of Gulbarga contains 15 towers and 26 guns, one of which is 7 5 m long A large mosque, 65 m. by 53 m in the fort, was constructed on the model of the mosque of Cordova in Spain, and is the only one of its kind in India.

Bijapur

1 96 Situated on the southern boundary of the Bhima catchment, Bijapur is rich in mausolea and buildings of architectural distinction Jama Masjid of 1537 A.D with its simplicity of design, its impressive grandeur and the solemn stillness of its corridors, stands unrivalled. The Gol Gumbad (the tomb of Mohammed Adilshah) has a tomb with an enormous dome of 44 m diameter which is the first of its kind in the world Its remarkable echo or whispering gallery attracts numerous tourists

ANDHRA PRADESH

Srisailam

1.97 Srisailam is the seat of one of the twelve Jyotirlingas of the country. Literally Jyotirlinga means a symbol of divine light. This Jyotirlinga was set up and worshipped by Lord Rama and the Pandavas in Puranic times and Krishnadevaraya and Chatrapati Shivaji in historic times. Krishnadevaraya and Shivaji who paid their homage to the Jyotirlinga built grand Gopuras indicating their dedication to the deity. The Srisailam high dam is under construction at this place on the Krishna river.

Nagarjunakonda

1.98 Nagarjunakonda is the fountainhead of the Madhyamika school of Mahayana Buddhism. It is named after Nagarjuna, a famous Buddhist monk. The archaeological excavations here are now kept in a museum on a hill top which became an island after the Nagarjunasagar dam was built.

Vijayapuri North and Vijayapuri South

1.99 With the construction of Nagarjunasagar dam two modern townships have sprung up on either flank of the dam, named Vijayapuri North and Vijayapuri South. Due to the dam and the Nagarjunakonda museum, they have become a tourist attraction.

Hyderabad

1.100 Hyderabad is the capital city of Andhra Pradesh. Being also the capital city of old Hyderabad State, and the seat of the Nizam's rule, it has several beautiful buildings and places of interest. Some of them are the Charminar, Golconda fort, Toli Masjid, Mecca Masjid, Jama Masjid, the University campus, the Public Garden and the Salarjung Museum. Among engineering achievements in and around the city are five bridges on the river Musi, the dams of Osmansagar and Himayatsagar and the Mir Alam Dam. The Mir Alam Dam is a multi-semi-circular arch dam located about three km. on the Hyderabad-Bangalore highway. It was designed and executed by French engineers about 105 years ago. It is the first of its kind in India.

Raigir fort

1.101 Raigir has an old Hindu fort of Kakatiya origin. About eight km. from Raigir there is a temple of Lord Narasimha on a hillock, by name *Yadagiri*, which attracts innumerable pilgrims every year.

Bhongir fort

1.102 Bhongir fort is the earliest hill fort in the Deccan, dating back to the 16th century, built on the crest of a granite hill, rising about 150 m. from the surrounding country The inner walls represent different styles of construction

Mettapalli

1.103 Mattapalli temple is situated at the confluence of the Musi with the Krishna. This sacred shrine of God Narsimha is famous for its carvings.

Amaravathi

1.104 Situated on the banks of the Krishna river, Amaravathi was the seat of the Satavahanas and is known for exquisite Buddhist relics. The Amaresvara temple is one of the ' Pancharamas '.

Jaggayyapeta

1.105 Jaggayyapeta is known for its archaeological excavations It has the remains of a Buddhist temple

Vedadri

1.106 Vedadri, a famous temple of God Narsimha, is on the banks of the Krishna 20 km. from Jaggayapeta in Krishna district It is visited by thousands of devotees throughout the year.

Pakhal lake

1.107 Pakhal Lake is the source of the Muniyeru river, covering an area of 34 sq km It is well known for its scenic beauty It is surrounded by a virgin forest which is a good game sanctuary covering an area of 872 sq km

Khammam

1.108 The fort of Khammam is said to have been built 900 years ago. It contains several precious stones of earlier periods

Mangalagiri

1.109 The temple of God Panakala Narasimhaswamy in Mangalagiri is famous and yearly thousands of pilgrims visit it.

Kondapalli

1.110 Kondapalli is famous for its ancient fort and the wooden toys made there.

Vijayawada

1.111 In Vijayawada is located the Krishna Anicut constructed a century ago. It contains Indrakiladri hill where Arjuna is believed to have fought with Lord Shiva and obtained the 'Pasupatastra'. On the top of a hill is the temple of Goddess Kanakadurga, one of the eighteen celebrated Shakti pithas worshipped all over India. Opposite to the Durga temple is the Gandhi Hill with a stupa. Over and around the Gandhi Hill is an institution started to propagate the ideals of Mahatma Gandhi. This was founded by Dr K L Rao, the eminent engineer of India.

Pillalamarri

1.112 Pillalamarri near Suryapet, contains three Kakatiya temples with exquisitely carved stone pillars.

Srikakulam

1·113 Srikakulam, in Krishna district, houses the famous temple of Andhra Vishnu.

Diamonds in Krishna Basin

1·114 Many historical diamonds have had their origin in the Krishna basin in Andhra Pradesh. The ' Great Mogul ', later cut to form the Kohinoor, and the ' Hope ' were obtained from the alluvial deposits on the Krishna at Kollur, in Guntur district The ' Pitt ' or 'Regent' stone, now the property of the French Republic, was obtained from Paritala in Krishna district

RESUME

1·115 In this chapter is described the trail of the great Krishna river across which has been built the world's largest masonry structure. The Krishna basin, its hydrology, tributaries, irrigation and power projects in different States of the basin, places of interest and shrines, the yield and its apportionment to various States have been described in detail. The reader will be told about the history of the project in the following chapter.

CHAPTER II

HISTORY

From time immemorial, the potential wealth of the waters of the Krishna was running waste into the Bay of Bengal. Whenever there was drought, small irrigation tanks dried up For want of large irrigation projects which could provide a carry over capacity, there was acute food shortage and frequent famines in India It was in the 19th century that Sir Arthur Cotton, the great British engineer, realised that only harnessing big rivers would increase food production in India Several high dams were built in the U.S A. and other countries in the early part of the twentieth century, but India could not dream of such projects. Had they been built earlier, they would have changed the economy of the country in irrigation, power and industrialisation. Because they were lacking, in spite of India's vast mineral, hydro-power and agricultural resources, the economy remained one of the poorest in the world. It was only after independence that projects of prosperity like the Bhakra Dam, Damodar valley development, Hirakud and Nagarjunasagar were taken up by the Government of India. This was due to the clear vision of Mr. Jawaharlal Nehru who took the initiative to start these projects which tapped the water treasures of India to make the country self-sufficient in food and for building up prosperity.

2.2 Nagarjunasagar is an outstanding monument built exclusively by Indian expertise With a potential of 1.4 million hectares of irrigation, with an installed capacity of 500 M.W. of electric power at the dam site, 60 M.W. at the head works of the right canal and 50 M W. at the head works of the left canal, the project will be a symbol of prosperity not only for Andhra Pradesh but also for the whole of India.

The valley of the Krishna between the confluence of the Tungabhadra and the sea is called the ' Lower Krishna basin '. This has a length of 451 km In this basin, sites exist at Siddheswaram, Srisailam, Nandikonda and Pulichintala for construction of high dams for the integrated development of the valley. In this part of the basin, there are wide areas adjacent to the river where rainfall is precarious, erratic and flashy. The Irrigation Commission of 1903 remarked that 'within this catchment lies a larger extent of exceptionally insecure country than is to be found in any other river basin in India '. This problem could only be solved by an integrated development of the river for irrigation and power.

2.3 It was in 1903 that the then composite Madras Government envisaged a reservoir across the Krishna at Pulichintala. The full reservoir level was proposed at a level of 68.43 m. with an irrigation of 2,42,000 hectares in Guntur district. Later on in 1930, the then Government of Hyderabad investigated a scheme for the construction of a dam near Nandikonda village in Nalgonda district. This was conceived as a joint scheme of the then Governments of Hyderabad and Madras But the Madras Government did not participate in the scheme. Consequently in 1952, the Hyderabad Government made out an independent scheme for the construction of a high dam across the Krishna at Nandikonda for irrigation of 3,24,000 hectares by a left canal in Hyderabad State and 94,000 hectares in Nandigama taluk of Andhra State and for the development of 168 M W. of power. The full reservoir level was proposed at 164.59 m. This proposal did not provide for conserving the necessary yield of the Krishna and for taking a right canal for development of irrigation in Andhra State

2 4 As the Government of Hyderabad made out a scheme for its benefit, the Government of Madras also investigated an independent scheme called the Krishna-Pennar scheme. This envisaged a dam at Siddheswaram on the Krishna with a full reservoir level (F.R.L.) of 273.0 m A link canal, called the Krishna-Pennar canal, was proposed to take off from the right flank of the Siddheswaram dam. This canal was to be dropped in the Pennar where a dam was proposed at Somasila with F.R L. at 115.2 m About 102 km. downstream of Somasila dam a barrage was proposed with crest level at 68.6 m and two canals were proposed to take off from the barrage, namely, the north canal to irrigate 1,96,000 hectares and the south canal to irrigate 3,00,000 hectares. The scheme also provided for the development of a second crop in the existing Krishna and Pennar deltas, besides power generation to the extent of 100 M.W. Provision was also made for feeding the new Gandikota reservoir across the Pennar with a discharge of 50.9 cumecs through the Krishna-Pennar west canal. The estimated cost of the scheme was Rs 1,303 million

The proposal to build a high dam at Nandikonda for joint benefit of Hyderabad and Andhra States was re-examined in 1953. It underwent drastic changes due to the ingenious discovery of Dr. K. L Rao that it would be possible to pierce the alignment of the right canal from Nandikonda dam through a gap in the mountains at Nakkirekallu and extend the canal through vast areas parched for water in the districts of Guntur and Prakasam right up to the borders of Tamilnadu. This discovery made it possible to propose a joint scheme by the then Governments of Hyderabad and Andhra for irrigation of millions of hectares and bring prosperity to the famine stricken coastal areas of Andhra,

Later, the dam site was inspected by Dr. Khosla. He was pleased as the foundations were attractive, being sound granite rocks. The river flows through a gorge for 80 km and the dam would store 27 per cent more water than the Bhakra with an unparalleled command area. This made the project one of the biggest in the world The Khosla Committee gave its approval to build a high dam at this site.

2 5 The Khosla Committee was set up by the Planning Commission to examine the various schemes for economic utilisation of the waters of the Krishna so that suitable schemes could be selected. The committee, after scrutinising various proposals, submitted the following integrated programme :

Stage I.

(*a*) A high dam at Nandikonda with F R L. at a level of 179.8 m. with two canals, one on the left and the other on the right. The left canal would irrigate lands in Hyderabad State besides those in Nandigama taluk of Andhra State

(*b*) A barrage across the Pennar as proposed in the Krishna-Pennar project with a canal to Madras. The Madras canal was to be fed with water let down from the tail-end of the Nandikonda right canal

(*c*) Improvements to the Kurnool-Cuddapah canal to carry a discharge of 169 9 cumecs. up to 112th km. for feeding its present ayacut and the ayacut of Kavali-Kanpur and Krishna-Pennar East Canal

Stage II.

A dam at Siddheswaram across the Krishna as proposed in the Krishna-Pennar project with F.R L. reduced from 273.9 m to 269.7 m. only with the Krishna-Pennar link canal with 283 cumecs capacity against 2122 cumecs proposed in the Krishna-Pennar project and the Krishna-Pennar west canal to be constructed for irrigation under its own area and with allowance for feeding the Gandikota reservoir with suitable adjustments.

Stage III.

A dam at Pulichintala across the Krishna with F.R L 68.4 m. for the development of power and for feeding a second crop area in the Krishna delta.

2.6 A conference was held by the Planning Commission on December 8, 1952 to consider the recommendations of the Khosla Committee. The committee, while drawing up an integrated programme, suggested

that further investigations should be made either for finalising its proposals or for recommending a particular scheme for inclusion in the first plan. The conference, accordingly, decided on the following programme of investigations :

(i) Remodelling the Kurnool-Cuddapah canal, including, if necessary, remodelling the Sunkesala anicut for this purpose. The Madras Government will complete the necessary investigations within four months.

(ii) *Nandikonda Dam* .

(*a*) The Government of Hyderabad will furnish existing data in full to the Madras Government and to the Planning Commission immediately.

(*b*) Detailed investigations on the canal system on the Madras side will be made by the Madras Government within ten months.

(*c*) Investigations made by the Hyderabad Government on the canal from the Nandikonda dam on the Hyderabad side will be brought up to date within three months.

(iii) *Pennar Dam* . The Madras Government may renew the proposals and after further investigations, place them before the Planning Commission within three months

(iv) *Pulinchintala Dam* : The Madras Government will carry out further investigations and bring the estimate up-to-date It will also examine the question whether a dam or a barrage should be provided. The entire investigation should be completed within nine months

(v) The Madras and Hyderabad Governments will submit a joint note in regard to the cost of the Nandikonda dam upto F.R L 144 8 m for the purpose of a second crop irrigation in the Krishna delta

Final Proposals

2.7 With the approval of the Planning Commission for building a high dam at Nandikonda for the benefit of Hyderabad and Andhra States, a joint scheme was submitted by both the Governments in 1954. The proposals of this joint scheme were finalised by the Andhra and Hyderabad States duly submitted by their respective Chief Engineers, Mr. L. Venkatakrishna Iyer and Mr. D. V. Rao, in April 1954.

The proposals comprised the following main features .

(i) A high dam was proposed to be built in masonry with an ogee spillway in the river portion with the crest at a level of 170.70m.

and fitted with 9.14 m. high lift gates and the non-overflow portions on either flank spanning across the gorge. Reach between relative distances hectometres 27.13 to 39.01 would be built in masonry whereas portions between 21 82 and 27.127 and 39.01 and 48 82 would be a composite dam ; and the reach 1 10 to 20 06 on the Hyderabad side would be an earth dam Nine river sluices measuring 1.83 × 2.74 metres were provided in the spillway dam with the sill level at 132 7 m. Three construction sluices were provided at a level of 90 06 m for facilitating diversion of the summer flow and also for releasing the irrigation supplies for the first and second crop irrigation in the delta during construction

(ii) A lined canal on the right side with the sill at 149 35 metres level having a capacity of 594.34 cu mecs at head reach, out of which 113 26 cu mecs would be let into the Pennar at the tail-end for the development of irrigation under the Kavali and Kanpur canals, proposed from the Sangam anicut.

(iii) A canal with the sill at a level of 149.35 m. of 311 00 cu mecs capacity on the left side for irrigation of 2,76,000 hectares of first crop and 49,200 hectares of second crop in Hyderabad State besides 84,000 hectares in the Nandigama taluk of Andhra State. The utilisation under this canal would be 4559 m cu m and 708 m cu m under Hyderabad and Andhra States respectively.

(iv) Development of a firm power of 75 M.W. at 0 6 load factor

(v) Development of an extra 61,500 hectares of first crop in Krishna delta in addition to the existing 4,30,000 hectares
Perennial irrigation of 10,000 hectares was also provided.

(vi) Development of 61,500 hectares of second crop in the Krishna delta

The proposals were scrutinised by the Central Water and Power Commission. After various revisions the commission gave the final shape incorporating the following salient features :—

(*a*) Dam with F.R.L at 179 83 m level.

(*b*) Right canal with the sill at 149 0 m. level with a capacity of 594.6 cu.mecs

(*c*) Left canal with the sill at 149 0 m with a capacity of 424 7 cu mecs

2.8 An investigation division called the Nandikonda project survey division was sanctioned by the Government of Hyderabad Nandikonda is the name of a village 0 9 km on the upstream side of the proposed dam The dam was named after the village as Nandikonda dam.

It will be interesting to note that there was a small breached tank by the side of Nandikonda village which was called Nandikonda tank which merged later into the gigantic Nandikonda reservoir.

2.9 The Nandikonda survey division was formed on December 22, 1954 by the author, who was then working as an engineer in-charge of the Wohar reservoir, which was being built for water supply to the city of Aurangabad in Maharashtra. The author had the privilege of being the first Divisional Engineer in-charge of the detailed surveys and investigations of the Nandikonda dam and its left canal. The Canal Project Circle was headed by Mr. M. Jafer Ali, Superintending Engineer. An estimate was sanctioned for constructing an approach road to the dam site The proposed road branches off from the Devarkonda-Miryalguda road from Peddavura village. The road measuring 19 km passes through a difficult hilly terrain

2.10 The investigations of the project comprised detailed surveys, drilling operations, preparing contour plans, selection of the final dam site and fixing the alignment of the left canal. The investigations of the dam and the left canal were conducted by Hyderabad State and investigations and surveys of the right canal were taken up by Andhra State

2.11 During the investigations of the project several difficulties were encountered Not even footpaths existed and the entire area was covered by forests infested with wild animals. It will be of interest to recall a few events. On October 25, 1955 at 3.00 a.m., when the author was returning to camp with his assistant and Mr. Zamin Ali Gazi, contractor, on the approach road to the dam site, a tiger crossed the road at Pottichelama As the tiger approached very near the jeep, the driver, M. Dharam Singh stopped the vehicle and shouted ' tiger ' ! ' tiger ' ! The tiger jumped across the road and ran into the forest. In a second instance, the operators left a bulldozer at 11th km. of the approach road. Next morning at 7, when they went to start the work, a cheetah was seen sitting on the bulldozer. In another instance, when a watchman went to fetch water and returned to his hut, he saw a cheetah comfortably sitting in his hut. But no damage was done, though the cheetah is a most wicked animal. On November 20, 1956 at 6 p.m. a tiger was sleeping at 19th km. of the Macherla road when the author was coming to the left flank in a jeep with his Assistant Engineers, Messrs. N. Rama Chander Rao and C. Janardhan Rao. From a distance, it appeared as though a person in coloured clothes was sleeping on the road. When we drove nearer and nearer within 90 metres, it was discovered that it was a tiger. The jeep was stopped. The tiger woke up, stared at us and bolted away into the forest.

On another occasion, two tigers that had become a menace to the cattle were killed on July 20, 1958. Cheetahs and bears were seen on several occasions in the project area.

The valley running parallel to the earth dam on the downstream side was a haunt for tigers. The author named this valley as ' Tiger valley '.

In spite of such difficulties, detailed investigations of the Nandikonda dam and the left canal up to 35 km were completed in a record time of 1½ years. The Assistant Engineers, Mr Prabhakar Rao, Mr. D. Rajendra Kumar, Mr. Y. Keshava Rao and Mr. S V. Sastry did commendable work in completing the investigations with speed and efficiency. The approach road of 19 km. in length was built by three contractors, Mr. Khader Sherief, Mr. Jagat Narain Pande and Mr. M Zamin Ali Gazi, in five months in a most difficult terrain where even drinking water was not available

2·12 When the approach road was under construction from Peddavura to the dam site, 5,000 labourers were employed. In the village of Chilakurti, which was situated half way, the investigation party was given shelter in the house of Mr. Nimmala Ramulu, a social worker Later Mr Hasnuddin, Assistant Engineer, brought tents and erected them near Potticbelama camp. No medical facilities were available in the camp The District Medical Officer Nalgonda was approached for medical aid. He expressed his inability as there was no provision in his budget for newly started projects in the district The project authorities were approached for immediate arrangements. As it took some time for the case being examined, prompt remedial arrangements were necessary to treat patients. A doctor by name, Dr. V. Chary was appointed on the muster rolls. He arranged for mass inoculations and treatment Later a regular hospital was established in the project with Dr. P. Rami Reddy as the first Civil Surgeon. He opened a hospital in the hutments of the labour colony.

Inauguration of the Project

2·13 After the completion of the approach road and a number of hutments at the dam site, the project construction work was commenced On December 10, 1955 the project was inaugurated by the late and great Prime Minister of India, Mr Jawaharlal Nehru He laid the foundation stone on the right flank of the dam and unveiled a pylon on the left flank. He crossed the Krishna from the right to the left flank by boat as there was no bridge at that time The right flank function was arranged by the Andhra State and the left flank one by the Hyderabad State The functions were attended by several officials and a huge gathering of hundreds of thousands people on each flank Distinguished among the

dignitaries were Mr. Chandulal M. Trivedi, the Governor of Andhra, Mr. B. Ramakrishna Rao, Chief Minister of Hyderabad, Mr. B. Gopala Reddy, Chief Minister of Andhra, Mr. N. Sanjeeva Reddy, Minister for P.W.D., Andhra, Dr. G S. Melkote, Minister for P.W.D., Hyderabad, Mr. D V. Rao, Chief Engineer of Hyderabad and Mr. L. Venkatakrishna Iyer, Chief Engineer, Andhra.

In his inaugural speech the Prime Minister remarked :

'When I lay this foundation stone here of this Nagarjunasagar, to me it is a sacred ceremony. This is the foundation of the temple of humanity of India, a symbol of new temples that we are building all over India.'

Naming of the Township and the Dam

2.14 On this auspicious occasion, Mr. Nehru, named the township on the left and right flanks Vijayapuri North and Vijayapuri South respectively These were the ancient names of the townships which existed on either flank of the Krishna in the submergence of the lake of Nagarjunasagar dam. The dam, as already stated, was named after the great Buddhist scholar and savant Acharya Nagarjuna who preached Buddhism in the valley which would subsequently be submerged. Thus, the Nandikonda project was renamed Nagarjunasagar project and the dam Nagarjunasagar dam to cherish the memory of the resplendent past

Archaeological Monuments of Nagarjuna Konda

2.15 The valley of Nagarjunakonda, Lat. 16°-31' N. and Long 79°-14' E., naturally fortified by hills on three sides and the Krishna on the fourth, i e on the west, with an area of 23 sq.km., is situated in the Pālnad taluk of Guntur district of Andhra Pradesh. The valley is now submerged under Nagarjunasagar reservoir, but Nagarjunakonda hill is about 6.1 m above the maximum reservoir level and has an area of about 82 hectares.

Discovery of Monuments

2.16 In 1926, Mr. A. R. Saraswati, Telugu Assistant to the Superintendent for Epigraphy, Madras, found several brick mounds and marble pillars, some of them bearing inscriptions in Prakrit and in Brahmi characters of the second and the third century A D. Later Mr. A H. Longhurst, Superintendent, South Circle, Madras, excavated the site from 1927 to 1932, exposed several ruins and collected most of the relic caskets and about 500 limestone sculptures in 1931-32. In 1938-40, Mr. T. N. Ramachandran continued the excavation of these sites. In 1955, when it was decided to build the Nagarjunasagar dam 13 km. on the downstream side of the Krishna from Nagarjunakonda, the entire



Mr. Jawaharlal Nehru, First Prime Minister of India on arrival for inauguration of Nagarjunasagar Project, Reception by Children and welcome by B Ramakrishna Rao, Chief Minister, Hyderabad State—10 Dec 1955—(*Para* 2 13)



Mr Jawaharlal Nehru, after unveiling the Pylon—(*Para* 2 13)

valley was to go under submergence. There was a demand from various Buddhist countries, among them Sri Lanka, Burma, Tibet, and Indo-China, to shift the site of the dam to save the valley. When Mr. Nehru laid the foundation of the Nagarjunasagar dam, he ordered that all the old relics be completely excavated and shifted into a museum to be built on the top of Nagarjunakonda hill. Mr. B. Ramakrishna Rao, the then Chief Minister of Hyderabad, told Mr. Nehru that the common man could not afford to go by launch to see the museum. Mr. Nehru retorted, ' Kya Nikamme-ki-Bat Hai '. ' What a talk of idle people? Would my people be poor after the completion of the Nagarjunasagar dam ! '.

Thereafter, the Archaeological Survey of India completed the excavations and shifted the entire antiquarian wealth of the valley. Under the able guidance of Mr R. Subramanyam, the work was taken up in right earnest and many sites were brought to light by 1960. It was discovered that Nallamalai hills, surrounding the valley, were called in ancient times ' Siriparvata ' or ' the mount of wealth ' and the city Vijayapuri (The abode of victory) founded by the Satavahana king, Vijaya-Sata Karana Ancient Vijayapuri with its great educational institutions had a population of nearly one hundred thousand as against the maximum population of 70,000 in the modern townships of Vijayapuri North and South during the peak construction period of Nagarjunasagar dam. This population dwindled to 20,000 on the completion of the dam.

History of Vijayapuri

2.17 In 196 A.D , Santamula of the Ikshvaku dynasty ruled over, Vijayapuri. It is claimed that this king was a descendant of Sri Rama* of the same dynasty. Santamula performed an Ashvamedha Yaga to establish his sovereignty. His horse was sent at the head of an army to various kingdoms. If any king were to seize the horse and thus challenge his suzeranity, that king had to face a war The yaga was similar to the one performed by Sri Rama when he ascended the throne in Ayodhya Excavations have revealed the Ashvamedha yaga ' *chiti* ' with the Homa kunda, the sacred bathing cistern and the bones of the horse lying buried by the side of the Homa kunda.

The founder of the Ikshvaku dynasty, was Vasishthiputra Chantamula who was perhaps an erstwhile subordinate of the Satavahanas. Inscriptions of Vijayasatakarni were also found in the valley. Chantamula was succeeded by his son, Virapurushadatta, who maintained the extent of the kingdom and enriched Vijayapuri with viharas and stupas His son was Ehuvala Chantamula, perhaps born to a Kshatrapa princess. His reign witnessed an attack on Vijayapuri by his commanders The king proved equal to the situation, drove away the enemy and constructed

* The Hindus worship Sri Rama as the incarnation of God

a temple to Kartikeya in token of his gratitude to the Lord who bestowed victory upon him. After Ehuvala, whose reign witnessed the rise of Hindu temples, the dynasty suffered an eclipse due to invasions by enemies including the Abiras. A memorial pillar to him was erected by his mother. Chanti-Sri, one of his sisters, had the freedom to embrace Buddhism This liberal outlook was followed by other women. Consequently, several ladies became Buddhists, while their husbands continued to be Hindus. Vijayapuri was overrun by the Pallavas in the fourth century A D.

According to Tibetan accounts, Nagarjuna lived on Siriparvata (Nagarjunakonda) for two hundred years during the times of the kings Udayana, Sucharita and Susakti. It is said that he is the same person as Bhadanta Nagarjunacharya mentioned in a Jaggayyapeta Sanskrit inscription He was the founder of the Madhyamika School of Mahayana Buddhism. He was also famous as an alchemist. Nagarjunakonda is named after him. Saiva temples came into prominence in the seventh century at Yelleswaram on the left bank of the Krishna. That is named after a commander, Yelisri of Vijayapuri.

During the period, Nagarjunakonda formed part of the Ikshvaku kingdom. After the dismemberment of the Chalukyan empire, the Kakatiyas rose to prominence with Anumakonda (Warangal) as their capital. They overpowered the Durjaya chiefs ruling over these regions and annexed these territories. In 1323 A.D., Warangal fell and those areas were overrun by the Muslim armies led by Malik Kafur and prince Juna. But soon reaction set in and independence was restored by the Musuri Chiefs After a century came the rise of Reddi power with Kondavidu as its seat.

Fifteenth century records show that the Reddy kings founded the fort of Nagarjunakonda with two gates at the gorge in the east of the valley. Four contemporary temples and the main gateway for the fort on the east still exist. The Reddis were supplanted by the Gajapathis of Orissa who established a viceroyalty at Kondavidu.

In the reign of Purushottam Gajapathi of Orissa, this fort served as a frontier citadel under the control of the local commander, Srinatha Raju Singarayya Mahapatra. In the reign of Purushottam, emperor Krishnaraya attacked this fort and ruined it in a single campaign.

In 1529 A.D. Krishnadevaraya placed it under the command of his general Ayyalaiya. But after the battle of Talikota in 1565, the region passed into the hands of the Qutab Shahis of Golkonda. Subsequently, the valley was granted as an agraharam (gift area) to the Pushpagiri Matha in Cuddapah district by a benevolent Golkonda ruler.

2 18 According to the Nagarjunakonda Buddapada inscription, certain teachers at Vijayapuri hailed from various countries. These have

been identified as Kasmira (Kashmir), Gandhara (Rawalpindi, Peshawar region), Yavana (Greek settlements in the Kabul valley), Vanavasa (Banavasi in North Kanara district of Karnataka), Tambraparnadwipa (Sri Lanka), and Kirata (Tibet), Tosali (Dhauli in Puri district of Orissa), Aparanta (Western India), Vanga (Bengal), Damila (Tamilnadu) and Avanti (Malwa).

The Monuments

2 19 In view of the submergence of the valley, the important stupas of the Maha-Chaitya, the bathing ghat, the Simhala Vihara, the Chaitya Griha and the Asvamedha stupa with a Swastika inset were transplanted on the Nagarjunakonda hill. The stadium and great monastery (university) were taken to the foreshore of the lake on the right bank at Anupu, where the Ranganathaswamy temple was also transplanted.

Scale models are kept in the museum on the main hill for the remaining important sites which could not be shifted Similar arrangements for saving the monuments were made in Nubia on the Nile in the United Arab Republic (U A R).

Pre-historic Remains

2.20 In the excavations were discovered hand axes, cleavers, and scrapers of quartzite These date back to the Early Stone Age They are displayed in the museum.

Tools of the Middle Stone Age, such as blades, arrow points, scrapers of quartzite and jaspery chert in smaller sizes have also been recovered. The Neolithic age developed burnished grey and red, and black hammers and axes, chisels and axe-hammers were used by carpenters. The buffalo and goat were domesticated Deer were hunted The people adopted finer crafts and lived in houses built of mud, each house enclosing one or two pits for storage, some of which were sealed with boulders when no more in use

At some sites were discovered burial traditions. In two cases a male and a female were buried in the same grave Infants were buried in urns

After a long time, the Megalithic people performed burials with stone circles enclosing heaps of stones covering the grave. These date back to 300 B.C. In one grave ornaments on the body of a female were found in position The burials mostly contained pots, iron objects and beads which were placed by the side of the dead.

Fortress of the Ikshvakus

2 21 The fortress of the Ikshvakus stood on the Krishna with rampart walls on north, east and southern sides with three gates. Outside the wall was a moat Within the walls once stood palaces,

barracks, stables, cisterns, baths, square wells of soak pits, a bathing pavilion and a tortoise shaped tank popularly known as the Asvamedha site.

Common man's Dwelling

2.22 Outside the fortress were rubble-mud walls sometimes with rooms and verandahs along the roads, cross roads and by-lanes, brick houses with flat roofs of Cuddapah slabs covered with lime. Certain quadrangular structures were in vogue There were goldsmiths, builders, sculptors, masons, potters, carpenters, farmers, artisans, blacksmiths, dancers and wrestlers.

Secular Building

2.23 A rectangular stadium with sixteen tiered galleries on all its sides originally stood on the south-western slope of the Phirangimotu hill and accommodated about a thousand persons at a time. With its acoustics it probably functioned as a theatre or a palace of musical performances. The extensive bathing ghat on the river bank was encased with Cuddapah slabs.

Near a pillared hall or the ancient burning ghat were discovered two sculptures, one showing a lady lying in state and another depicting a Sati scene. Nearby was found a sculpture representing the squatting Mother Goddess. Near the bathing ghat is the temple of Pushpabhadraswamin. In close proximity the Saivadeva temple was erected by Commander Elisri.

Buddhist Sites

2.24 More than thirty Buddhist units came to light outside the Ikshvaku fortress stretching all over the valley. The Mahachaithya as a relic stupa was erected by Santisri, a sister of Vaisishthiputra Chantamula. This has a diameter of 27.5 m. with Ayaka pillars on platforms in the four directions.

This platform for stupas entered the architecture of Nagarjunakonda from Sanchi, Ajanta, western India and Gandhara. The Ayaka platforms on four sides of most of the stupas formed another feature. Five pillars stood on each of the platforms, probably representing Buddha's principal life scenes. The sculptures invariably show the stupas within an outer rail, but the stupas at the sites probably did not have any rail as such.

Island Museum

2.25 By 1960 A.D. the excavation work in the valley was practically over. During 1963 most of the important antiquities reached the Nagarjunakonda hill top The remaining collections were kept at Anupu above the submergence level of the reservoir. By 1965 all the necessary materials

for organising the new museum were collected on the top and finally the museum was inaugurated on April 23, 1966 by Mr. M. C. Chagla, the then Union Minister for Education Thereafter, the valley was gradually submerged and a motor launch service was introduced

The museum is notable for the following facts ·

(i) It occupies a lofty position on a hill surrounded by vast waters of the Nagarjunasagar lake, affording the visitors a scenic trip by motor launch.

(ii) Its art objects are housed in one of the best buildings in India, especially designed for the purpose

(iii) Its collections are varied and enormous, dating back from the pre-historic period to the 16th and 17th centuries

(iv) The exhibits are arranged on the lines of the latest international standards

Gallery I is the treasure of the museum presenting a colossal Buddha, Yakshas, Ayakapattas, moonstones, cornice beams, jewellery, beads, coins, relic caskets and pre-historic as well as post-historic objects.

Gallery II exhibits chronologically Buddha's life scenes and Jatakas as depicted in the slabs, cornice beams, pillars, etc , stucco and terracotta objects, pottery and some Hindu sculptures

Gallery III contains miscellaneous sculptures depicting chronologically Buddha's life scenes and Jatakas, inscriptions and medieval sculptures

The hall of the models exhibits in scale the vast valley with one hundred and twenty excavated sites located on it, contours and surroundings after submergence Fifty plaster models representing important excavated sites are arranged in a running wall show case.

Pre-historic and Post-historic Tools and Implements

2.26 Early Stone Age man was a hunter and produced hand axes and sometimes used them as spearheads or as broad sharp-edged cleavers for cutting and digging The mode of manufacturing these tools is explained in the show case through models.

The Middle Stone Age man prepared arrow-heads for his bows and also used blades and scrapers.

The Late Stone Age man used microliths Several microliths fixed up in the semi-circular groove of a wooden handle formed a sickle as illustrated by a model in the show case. This would show that he had some knowledge of agriculture.

The Neolithic man used more developed and polished axes, chisels and hammers He knew cultivation, carpentry, pottery-making, etc., and lived in hutments.

The Megalithic man entered a much more developed phase of life with the use of iron knives, arrow heads, spear-blades, wedges and axes and highly advanced pottery.

Stone Sculptures

2.27 Ikshvaku sculptures are made exclusively of limestone, quarried from the Nadikudi and Dachepalli regions, situated along the present Macherla-Guntur rail track. The medieval sculptures are fashioned in the local stone of black basalt, red or buff sandstone, granite, etc. The subjects of most of the earlier sculptures are drawn from Buddhist works such as the Jataka Stories. The medieval sculptures depict generally Hindu Gods and Goddesses and sometimes Jain figures

The scenes from Buddha's life generally comprise prediction, conception, birth, interpretation of signs, first meditation in the pleasure garden, the four visions, renunciation, lamentation of Siddhodana and Yasodhara, worship of relics, immersion bowl of Natranjana, enlightenment, first meal after enlightenment, the first sermon, the conversion of the noblemen of Varanasi, meeting Bimbisara after enlightenment, conversion of Nanda, protection by Muchalinda, visit to Yoshodhara and Rahula, preaching to Maya in the Tushita heaven, conversion of Angulimala, Naga Uruvela, Naga Apalala, King Kappina and Yaksha Alavaka, Indra's visit to the Buddha, and the Mahaparinirvana.

It is only at Nagarjunakonda that a dome slab depicts the touching scene of the lamentation of Siddhodana and Yasodhara his wife at the departure of Buddha from Kapilavastu.

Nanda, a cousin of the Buddha, went away with him from his palace to the monastery leaving behind at home his weeping wife Sundari. In a sculpture the shyness on Nanda's face while begging for alms in the streets and the curiosity of the children with toy carts gazing at him are remarkable

Specially interesting is a pillar showing two bearded Scythian figures with their cloths stuffed with cotton and another pillar showing a Scythian soldier fighting.

Medieval sculptures are represented in the highly ornate Yoganarasimha of the 13th century, a Jain Tirthankara of the 15th century, Mahishamardini Durga and Nandi of the 16th and 17th centuries and Siva and Durga of the 17th and 18th centuries.

The Nagarjunakonda artists, while portraying the themes, utilised the foreground, background and horizon giving more weight to the figures than to the natural background in contrast to the earlier tradition of Sanchi, where nature almost overshadows the figures.

Nagarjunakonda art was thus a fusion of heterogeneous and indigenous currents of thought.

Ancient Coins

2 28 South India had a brisk trade with the Roman empire in the early Christian era. Gold coins of Tiberius and Faustina have been unearthed at Nagarjunakonda.

Relic Caskets

2 29 A gold relic containing bones, gold and silver flowers was kept in a silver casket which in turn went into a terracotta stupa and this stupa into a stone stupa. In the rest of the cases, were kept respective stupas in groups of two or three caskets

Ancient Jewellery

2.30 The Megalithic age provided the earliest set of spiral gold ear-rings, small cylindrical beads of gold, originally arranged in a string along with silver beads In one of the viharas a gold necklace with a coin of queen Faustina and a pair of gold ear-rings were discovered.

Preliminaries for Project Construction

2 31 The construction of the dam started with Mr. Chakravarti as Administrator, Mr. M Jaffer Ali as the first Chief Engineer and Mr. S L Saksena as Financial Adviser and Chief Accounts Officer. To start with six two-roomed thatched rest houses were built for the officers and a number of tents on the left bank. This was followed by 1,000 quarters for the staff and 800 labour hutments. Drinking water was supplied from the Krishna by pumping it into tankers which were hauled by tractors to various camp sites The camps were lighted by a small Diesel driven generator of 60 kw. capacity. Similar arrangements were made on the right bank for a colony Communications between the left and right banks was by ferry. The offices of the Administrator, the Chief Engineer and the Financial Adviser and Chief Accounts Officer were located in Hyderabad, in a common building. These preliminary arrangements made for a population of 5,000 were gradually supplemented by elaborate arrangements for an ultimate population of 72,000. The facilities provided have been described in detail in Chapter XIII.

Foundation Excavation of Nagarjunasagar Dam

2.32 The excavation of the foundation of the dam was started on February 6, 1956. Mr. Kunche Satyanarayana and Mr. Sagi Ramakrishna Raju, contractors, gave effective co-operation. Mr Satyanarayana unfortunately died at the dam site on June 13, 1965. He was popular among the labour, the officers and the contractors. On the day following his

death his photo was carried in a procession by all sections of the people round the colonies and the works were closed as a mark of respect to the departed.

Important contractors who participated in the excavation of the foundation were Mr. Kunche Satyanarayana, Mr. Laxminarasu and Mr. S. K. Iyer.

The excavation of the dam comprising the large quantity of one million cu.m. was completed by February 1964.

Materials and Transport

2.33 The most important material, i.e., cement was supplied by Macherla Cement Factory located at a distance of 22 km. from the dam site. This factory, which was specially commissioned to feed cement to the Nagarjunasagar dam and canal works, started its supply to the dam in April 1959. The maximum daily draw was 1,500 tons of cement in 1965. For the supply of cement, a railway line was laid from Macherla to the dam site. It started functioning on January 1, 1959.

In the initial stages, stone was quarried from granite quarries in the bed of the reservoir from a distance of 3.2 km. and on the submergence of these quarries, from a distance of 10 km. Stone quarries were also opened at Nagarjunakonda on the right bank at a distance of 16 km.

In the initial stages, sand was carted from Rayavaram stream from a distance of 11 km. from the submergence area. Later the supply was switched over to the Halia river and its distributaries from a distance of about 29 km. The entire transport of stone and sand was done by lorries.

Surki, which was added to cement, was manufactured from the earth available in the local stream at a distance of 3.2 km., in the initial stages and 16 km., later.

An airstrip was built at a cost of Rs. 6,50,000 on the right bank.

Diversion Works

2.34 The diversion of the river to facilitate raising of the dam in the gorge portion was commenced in 1956 by building a masonry coffer dam in one-third portion of the river bed, and was completed in parts in the subsequent years. Block 41, which was the lowest, was the last to be tackled. This work was completed in 1963 and water was diverted through six construction sluices. Finally, the summer flows were diverted through a horse-shoe tunnel and the diversion sluices were plugged completely in 1964.



Laying last stone to mark 2832 cum progress by Mr Hafiz Mohd Ibrahim, Minister for Irrigation & Power, Govt of India with Mr. G. A Narsimha Rao, Chief Engineer (7-12-1959)—(*Para* 2.35)



Inauguration of Kamala Nehru Hospital by Mrs Indira Gandhi with Dr T Rangiah 6-12-1963—(*Para* 2.40)

Construction of Masonry

2.35 When a few blocks were ready in the bed of the river with the foundations excavated, duly wedged and barred and the consolidation grouting completed, the construction of masonry was started

The first stone for the masonry construction was laid by Mr S. K. Patil, Union Minister on July 12, 1957 and the progress continued building up. On February 7, 1959 the daily progress was built up to 2,832 cu.m of masonry when the last stone was laid by Mr. Hafeez Mohd. Ibrahim, the then Union Minister for Irrigation and Power

From 1961 prizes were awarded to contractors giving the maximum output in the masonry construction The first prize of a gold medal was carried away by Mr. T Chandra Sekhara Reddy. Later on, the highest progress of work was maintained by Mr T. Subbarami Reddy, consecutively for four years, and he was also awarded gold medals by the project authorities and ultimately by the Prime Minister of India

By December 1965 the masonry reached an advanced stage of construction, 85 per cent of the work having been completed. The dam was raised to a height of 79.2 m in the non-overflow section and 52 7 m. in the spillway section. A peak progress of 7236 cu m of masonry and concrete was achieved on December 24, 1965. To mark this event in the history of the dam, the last stone was ceremoniously laid by the Chief Engineer, Mr A. P. Ranganatha Swamy in Block No 45 where, on a single block, the maximum progress of 376 cu m. was given by Messrs Harbans Singh, Harnam Singh, contractors, who were awarded a gold medal for their outstanding work

2.36 The following Executive Engineers were responsible for the maximum out-turn in their operational sectors

(1) Mr T. K Mohana Rao, left bank masonry
(2) Mr. M Sreerami Reddy, right bank masonry
(3) Mr. V. Somasankara Rao, batching plants.
(4) Mr Y. P. C Chowdary, rubble supply.
(5) Mr. G. Narayya, operation of monotower cranes
(6) Mr R Venkateswara Rao, left bank concreting
(7) Mr D. Rajaiah Raj, right bank concreting
(8) Mr. Misbahuddin Khan, electrical supplies

The quality of the work was effectively controlled by Mr Rama Brahmam, Superintending Engineer, Inspection and Control, assisted by Inspection Executive Engineers, Messrs K V. Suryanarayana Murthi and M Bhaskara Rao. The transport of mortar was efficiently organised by Mr G. K. Reddy, Superintending Engineer, assisted by Mr. K. Rama Rao, Executive Engineer and Mr. Sambasiva Rao, Executive Engineer.

2.37 For recording high targets of construction, the labour worked spontaneously and several contractors established a record of more than 283 cu.m. (10,000 c.ft.) of masonry on single blocks on December 24, 1965. Their progress is given below :

Block No	Progress in cu.m.	Name of the contractor
38	306	Mr. V. Nageswara Rao.
39	297	Mr. V. Nageswara Rao.
40	365	Mr. T. Yogaiah Naidu.
41	320	Mr. G. V. Krishna Reddy.
42	371	Mr. K. Venkata Krishna Rao.
45	376	Messrs. Harbans Singh and Harnam Singh.
48	308	Mr. T. Subbarami Reddy.

It will be seen from the above that Mr. V. Nageswara Rao built 603 cu.m. (306+297) of masonry on a single day and more than 280 cu.m. on each of blocks 38 and 39. This was a unique achievement by any contractor in the history of the construction of the dam. For this outstanding achievement he was awarded a gold medal by the Prime Minister of India.

During this historic period in the dam construction Mr. Rama Krishnam Raju maintained the colossal supply of metal, 1700 cu.m per day. The metal was broken manually and carted by lorries. For his unique accomplishment he was awarded a gold medal by the Prime Minister of India.

2.38 But for the extraordinary talent and team work, coupled with the concerted and co-operative efforts of the above-mentioned engineers and contractors, it would not have been possible to record unparalleled targets of construction Their unprecedented work will be appreciated by the people of our country for generations to come

The value of the work done on a single day works out to Rs. 0 65 million This progress was achieved with minimum machinery supported by a labour force of 29,000 of various trades including the departmental staff.

Later, in 1966 was set up another high record of masonry construction in blocks where monotower cranes were utilised for supply of stones. Mr. Omprakash Mittal, a contractor, showed the extraordinary progress of 249 cu.m of masonry on Block No. 24 on June 2, 1966. Mr. M. Zamin Ali exhibited an unparalleled progress of 382 cu.m on two blocks i e.,

19 and 21 on June 18, 1966. These contractors were awarded gold medals by the Prime Minister.

Last Stone of Masonry of Dam

2.39 The construction of masonry in the dam came to a close with the masonry in the apron portion of the spillway This last construction of masonry was done on May 15, 1958 by Mr. Zamin Ali and the last stone was laid by the author at a simple function attended by the labour and staff of the project.

IMPORTANT INFRASTRUCTURES

(*a*) *Educational Institutions* :

2.40 The dam organisation has one high school in Vijayapuri North (Hill Colony), one high school in Vijayapuri South and one middle school in Pylon Colony. The students of Nagarjunasagar High School of Vijayapuri North sent a congratulatory telegram to the late Prime Minister, Mr. Jawaharlal Nehru on his birthday, November 14, 1957. In response to the telegram the Prime Minister sent the following message to the students in his own handwriting.

Prime Minister's House,
NEW DELHI

' I am deeply grateful to you for your message of good wishes on the occasion of my birthday anniversary. I feel overwhelmed by the affection and goodwill I receive and it is difficult for me to find suitable words to give expression to my feelings '

JAWAHARLAL NEHRU

New Delhi,
November 25, 1957

(*b*) *Hospitals* ·

There is a 110-bed hospital in the Hill Colony which was inaugurated by Mrs Indira Gandhi, daughter of Mr Jawaharlal Nehru on December 6, 1963 This hospital gained high reputation by serving patients not only from the dam area but also from far off places. It is named Kamala Nehru Hospital in memory of India's

celebrated freedom fighter, social pioneer and the consort of India's first Prime Minister, Mr Jawaharlal Nehru Dispensaries were also provided in the Pylon and Bandlakarva colonies and in Vijayapuri South.

The Ladies Club of Nagarjunasagar dam headed by Mrs. Leela Ranganatha Swamy organised fêtes and entertainments and collected Rs. 50,000 and the Government of Andhra Pradesh gave Rs. 15,000. With this amount a well-equipped children's ward with 20 beds was added to the Kamala Nehru Hospital. The ward was built by Mr. V Nageshwara Rao, Contractor of Messrs. Southern Engineering Works and opened by Mr Morarji Desai, the then Finance Minister of India, on July 15, 1967. The ward was named after its pioneer as 'Vijaya Laxmi children's ward.'

(*c*) *Labour Night Schools*

Night schools were organised to impart education to adult boys and girls of the labourers who were working on the dam during day time and who were deprived of regular education. As two languages were spoken by the labourers, Telugu and Tamil, classes were run in both languages.

(*d*) *Labour Rest Sheds, Children's Crèches and Cafeterias*

Shelters were built on the left and right flanks to serve as rest sheds during lunch hours Children were provided with crèches Cafeterias named after Annapurna were opened both on the left and right flanks where each dish was sold at six paise. Later due to the increase in the cost of foodstuffs, the rates were raised to 10 paise per dish Annapurnas were maintained until the dam construction ended in 1968.

(*e*) *Construction of Temples, Mosques and Churches*

In 1956, an image of Hanuman existed in the Pylon area where later a Ramalaya was built with beautiful images in 1969. The images were brought from Jaipur (Rajasthan). The Hanuman image was installed facing those of Rama, Laxmana and Seeta. The temple, built on the left bank, was named Kodanda Rama Swamy temple. The entire construction was with the help of public donations The dhwaja stambha was given by one donor, Mr Sagi Ramakrishna Raju hailing from Godavari district. The temple was ceremonially inaugurated on December 9, 1968 by His Holiness Sri Gayatri Peethadhipathi and Kalahasti Swami. There was poor feeding for nearly 12,000 persons on this auspicious occasion.

A Ramalaya was also built on the right flank with public donations with the keen interest taken by Mr. Sreerami Reddy, Executive Engineer. This temple has beautiful idols.

In 1960, a beautiful temple of Shiva was built on the left bank by a great devotee, Mr Bh. V. L. Narasimha Murthy, Assistant Engineer

A mosque was built on either bank. The left bank mosque was built through public donations by Mr. Zamin Ali Gazi in 1958, and the right bank mosque came into existence in the same year.

Beautiful churches were built in the Hill Colony and in the Pylon Colony by Father L. Peezoni with public donations These churches were designed by Mr. Sabir Hussain, Architect, who also played an eminent role in developing various architectural features of the entire project

A temple of Veera Brahmam was also constructed by the workers near the workshop For all these temples, mosques and churches, contributions were made by people of all religions and by the rich and the poor

(f) Teachers Training College and Other Institutions

With the completion of the dam, the laboratory building and stores sheds became surplus Mr. P. V Narsimha Rao, the then Education Minister, gave orders to convert these vacant quarters into educational institutions He inaugurated a Teachers Training College in the laboratory building on November 4, 1969. He also ordered the construction of laboratories and workshops for the Engineering College in the Hill colony. Thus Vijayapuri, which was a great centre of education in ancient times was revived with educational activities in modern sciences

OUTSTANDING EVENTS

2.41 After the inauguration of the project on December 10, 1955, by Mr. Nehru, the following were the outstanding events :

(*a*) On August 9, 1957 the late Dr. Rajendra Prasad, the President of India, graced the project by his visit. He gave interviews to all the officers and gave them his blessings

(*b*) On October 12, 1959 Mr. Nehru came to the project for the second time and inaugurated the airstrip. He congratulated the engineers and workers for their outstanding works, including the modern temple (Nagarjunasagar dam) He called all the officers of the project and advised them that they should give the highest importance to solving labour problems promptly

(*c*) A mahayagna was performed on August 16, 1960 in the Pylon Colony with the co-operation of officers, merchants and workers

Pandit Narendraji of Hyderabad organised the Homams conducted by learned pandits who came from all over India. On the seventh day mass poor feeding of 22,000 persons was arranged. This was the biggest feast ever held in the history of the area.

(*d*) Following a country wide appeal by Mr. Nehru, the Dam Organisation took the earliest step in collecting Rs. 1,00,001 made up of one day's pay from every worker. This amount was sent to the Defence Fund on November 7, 1962. The maximum amount of Rs 12,001 was contributed by Mr. Zamin Ali Gazi, a contractor

(*e*) Mr Lal Bahadur Shastri, the late Prime Minister, visited the project on December 12, 1965. An amount of Rs 1,00,000 and 5,000 grams of gold were presented to him for the National Defence Fund. The gold was collected from house to house by some of the ladies of the Hill Colony, Mrs. M. Tayamma, Mrs Nirmala, Mrs. Shakuntala, Mrs. Lalitha and Mrs. Kamala The ladies of the Right Canal Club, Mrs Sridevi, Mrs. Kusuma, Mrs. Rangamma, Mrs. Padmavati and others staged a drama at Macherla The function was highly appreciated as a mark of their sincerity in the service of the country.

(*f*) Delegates to the sixth Congress of the International Commission on Drainage and Irrigation visited Nagarjunasagar dam on January 23, 1966 They expressed great satisfaction at the operation and methods of construction mostly by manpower. Mr. George O. Pratt, an engineer from the U.S.A. remarked, 'Nagarjunasagar dam is especially impressive because it is an actual living demonstration of the economic utilisation of one of the great resources of India's manpower.'

(*g*) After strenuous work of ten years day-in and day-out, the efforts of the organisation bore fruit. Men and women from all over India had toiled at the construction of this mighty structure and successfully raised stone by stone and brought the dam to store water over the sill level of the canals by June, 1966. The reservoir filled up to a level of 149 m. by August 1, 1966 and the Krishna river started flowing over the spillway.

(*h*) The waters of Nagarjunasagar were ceremonially let into both the canals in August, 1967 by Mrs. Indira Gandhi, then Prime Minister. She had the unique privilege of letting out the waters of the dam, the foundation stone of which was laid by her great father, Mr. Jawaharlal Nehru in the same capacity as the Prime Minister of India On this happy occasion the two canals were named after the great Prime Ministers. The right canal was named Jawahar Canal and the left Lal Bahadur Canal. At the headworks of each canal the statue of the Prime Minister was installed to watch the blue waters of the Krishna, emerging from the reservoir and gushing into the canals for the progress, plenty and prosperity of India.

On that day Mrs. Gandhi also inaugurated the Saint Joseph Convent School in the Hill Colony. This outstanding and beautiful structure, situated on the main hill colony road, facing the lake, was built by Mr. Ghose Khan, a contractor and was designed by the architect, Mr. Sabir Hussain.

(i) Dr. Zakir Husain, the President of India, paid a visit to the dam on September 5, 1967. He was deeply impressed with the stupendous progress of the work and made the following remarks :

' I was thrilled to visit this place. A great seat of light and learning during ancient centuries, it has now become in Jawaharlalji's significant words a neat place of pilgrimage for modern India Conceived with great vision and executed with extraordinary competence, this project, into the building up of which has gone the devoted work of thousands of our countrymen over quite a decade, justifiably makes one feel proud of one's countrymen.

The waters of the Krishna which were just passing into the sea have been harnessed and from here provide power, light and irrigation to a very large number of our fellow citizens and contribute in no small measure to the progress and prosperity of the country.

I congratulate all connected with this project on their admirable achievement and trust that resources will be made available to finish what remains to be completed to maximise the utility of this great venture '.

(j) In December 1970 an international children's village camp was held at the dam site, in the campus of Vijaya Vihar. Children from thirteen different countries participated Boys and girls were selected from the age group of 10 to 12 years. Each country was represented by two children The children were experts in some talent or the other such as music, dance painting and sports This gave an opportunity for children from various countries with different languages, culture and food habits to get together to establish international brotherhood. Such camps are held once a year in different parts of the world. The camp that was organised at Nagarjunasagar dam had the beautiful surroundings of the lake, the picturesque mountains, coloured fountains and beautifully lighted camps, a swimming pool and facilities for boating in the lake. Visits were arranged to the island museum Various performances wers held so that the children could display their talents At the end of the camp, prizes of toys and idols of gods were given to them as souvenirs

2.42 Mr Kasu Brahmananda Reddi, the then Chief Minister of Andhra Pradesh took interest in organising and making the camp a great success and he was assisted by Mr Thakur V Hari Prasad, the Chairman of the Viswabharati Welfare Trust.

Chronology of Events

2 43 The important events concerning the historic construction are chronologically summarised as under :

Conception of the project on the Krishna river ..	1903
Preparation of the first preliminary project report for constructing a dam across the Krishna for irrigation in the former Hyderabad State .	1930
Preparation of a detailed project report by the States of Hyderabad and Andhra (Joint report) .	1954
Commencement of the construction of the approach road to the dam site ..	August 1, 1955
Functioning of Nagarjunasagar Control Board .	1954
Laying of the foundation stone of the project by Mr. Jawaharlal Nehru, the Prime Minister .	December 10, 1955
Commencement of the construction works at the dam site. .	Feb. 10, 1956
Completion of the masonry coffer dam.	June 30, 1956
Commencement of masonry for the dam with the inauguration by Mr S K. Patil, Union Minister for Irrigation and Power .	July 12, 1957
Opening of the bridge across the Krishna by Mr N. Sanjeeva Reddy, Chief Minister of Andhra Pradesh ..	Nov. 28, 1957
Visit of Dr. Rajendra Prasad, the then President of India	August 9, 1957
Opening of the Project House by Mr. J V. Narasinga Rao, Minister for P.W D , Andhra Pradesh ..	December 11, 1958
Commissioning of the Macherla-Nagarjunasagar railway siding .	Jan. 1, 1959
Attainment of 100,000 Cft. (2830 cu. m.) of masonry .	Feb. 7, 1959

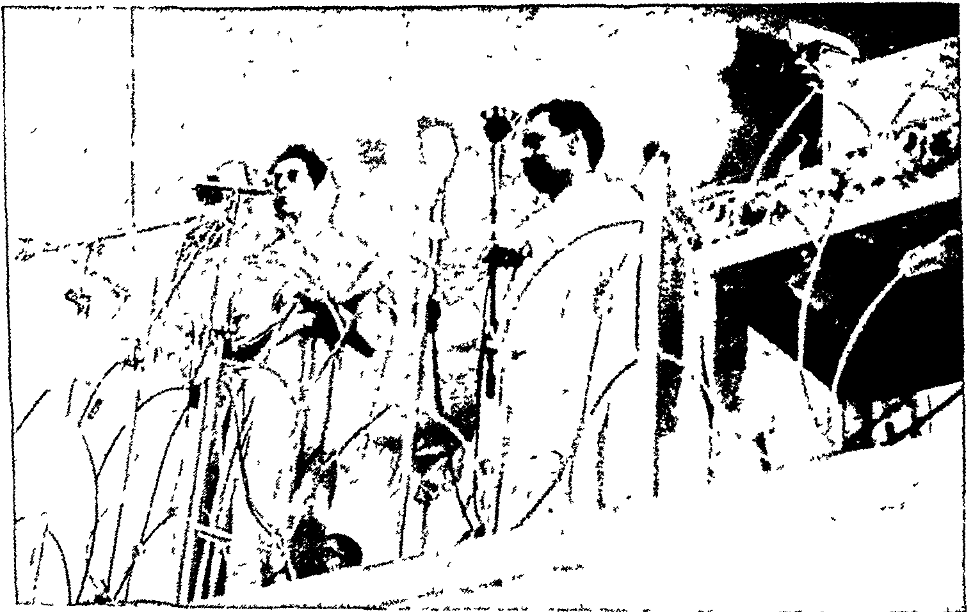


Visit of Dr. Rajendra Prasad, President of India with Dr N Sanjiva Re[illegible]
Chief Minister of Andhra Pradesh—(*Para* 2 41)

Vis[illegible] of Mr. Lal Bahadur Shastri, Prime M[illegible] of [illegible] with M[illegible]
and Dr K L. Rao 12-12-1[illegible]5—(*P*[illegible] 2 41)



Ladies of Nagarjunasagar Dam Mrs. D Nirmala and M. Tayamma, presenting gold ornaments to Mr Lal Bahadur Shastri, for defence fund—(*Para* 2.41)



Letting of waters into Jawahar Canal, by Mrs Indira Gandhi, Prime Minister of India on 4-8-1967 with Mr P V. Narasimha Rao, Minister for Education, and Mr K Brahmananda Reddy, Chief Minister, Presiding—(*Para* 2.41)



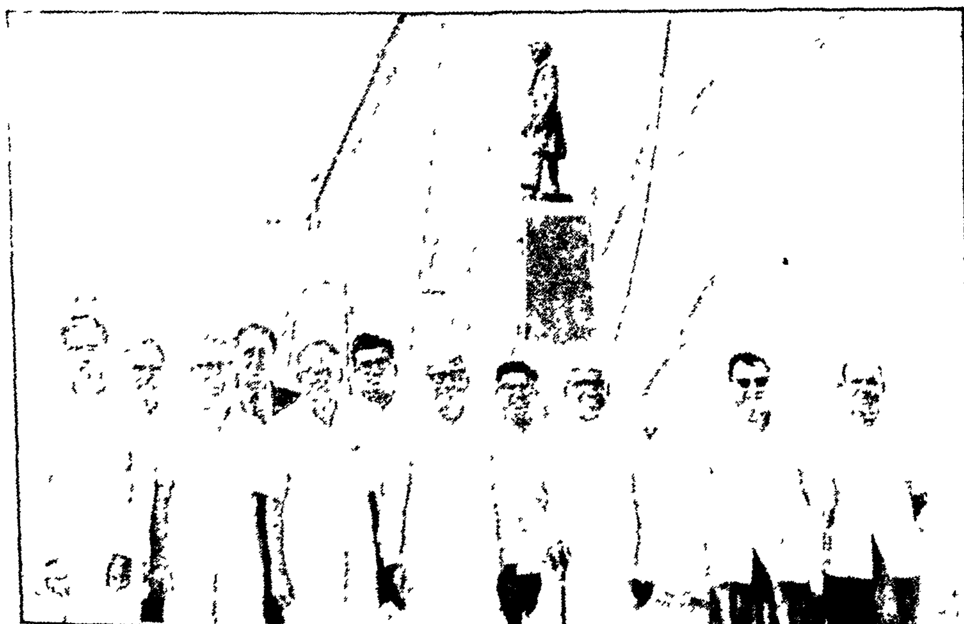
Visit of Dr Zakir Hussain, President of India 5-9-1967—(*Para* 2 41)



President of India Mr V. V Giri at Ramalaya Temple, Nagarjunasagar Dam (*Para* 2 41)



Visit of Mr Fakruddin Ali Ahmed, Union Minister for Food, with Mr A C Subbareddy, Minister for Public Works, Andhra Pradesh and Dr K L Rao, Union Minister for Irrigation & Power, Govt. of India—(*Para* 2.41)



Visit of Mr Jagjeevan Ram, and Dr K L Rao, Union Ministers, Govt of India, with Mr K Brahmananda Reddy, Chief Minister—(*Para* 2 41

Inauguration of the airstrip by the first landing of the plane with Mr. Nehru.	Oct. 12, 1959
Performance of a mahayagna in the Pylon Colony of Vijayapuri North ..	August 16, 1960
Opening of Vijayavihar Guest House by Mr. N. Sanjeeva Reddy, Chief Minister of Andhra Pradesh ...	April 10, 1963
Construction of the diversion sluices.	May 1963
Inauguration of the excavation of the irrigation-cum-diversion tunnel by Mr A. C. Subba Reddy, Minister for Irrigation and Power, Andhra Pradesh	Nov. 26, 1963
Inauguration of the Kamala Nehru Memorial Hospital by Mrs Indira Gandhi. ..	December 6, 1963
Laying the foundation stone for Tourist Annexe and Rest house in Nagarjunakonda by Mr. Kasu Brahmananda Reddy, Chief Minister of Andhra Pradesh .	July 26, 1964
Plugging the construction sluices .	December 1964
Inauguration of the diversion-cum-irrigation tunnel by Mr. A C Subba Reddy, Minister for Public Works Department, Andhra Pradesh	June 11, 1965
Visit of Mr Lal Bahadur Shastri, Prime Minister	December 12, 1965
Maximum masonry progress .	December 24, 1965
Visit of Delegates of International Commission on Irrigation and Drainage .	Jan. 23, 1966
The spillway of Nagarjunasagar dam brought to the crest level of 546 feet.	May, 1967
Opening of Vijayalaxmi Children's ward by Mr. Morarji Desai, Deputy Prime Minister of India ..	July 15, 1967
Inauguration of letting out waters of the Nagarjunasagar Lake into the canals by Mrs Indira Gandhi, Prime Minister	August 4, 1967
Laying thelast masonrystone of the dam	May 15, 1968
Erection of the first crest gate ..	Jan. 1969

Visit of Mr. V.V. Giri, President of India.		1970
International children's camp	..	December 1970
Erection of all the crest gates completed.		May, 1972

RESUME

2·44 The story of the construction events of the great national monument Nagarjunasagar dam has been narrated. These activities have been chronologically recorded. These unparalleled events will perpetuate the memories of the great builders and will inspire posterity to make efforts to eradicate poverty by providing greater irrigation and power facilities to our country. The history of this construction activity will also create self-reliance and admiration for generations to come

CHAPTER III

GEOLOGY AND FOUNDATION TREATMENT

The site of the Nagarjunasagar dam lies about 2.50 km. below Nandikonda village which went under submergence of the reservoir It is situated at 16°-34'—23" North Latitude and 79°-18'—47" East Longitude, between the confluence of the Pedda Vagu, a tributary of the Krishna, and the village of Chintapalam, in Miryalguda taluk of Nalgonda district. It is 149 km from Hyderabad, the capital of Andhra Pradesh The approach road to the dam site is 21 km. long, taking off from the Devarkonda-Miryalguda road from the village of Peddavura The site is also connected by road to Macherla railway station, which is 22 km. from the dam site. It is in Gurzala taluk in Guntur district All the roads connecting the dam site are dust free. There is also an airstrip, five km. to the south-west of the dam

Topography

3·2 After its confluence with its tributary, the Tungabhadra, the Krishna enters a gorge through the Amarabad Nallamalai plateau. The high hills extend up to the village of Chintalapalam, six km. down below the dam site. ·The river opens out at the site of the dam The minimum width of the gorge at the dam site is about 914 metres, while the total length of the dam is 4839 metres of which the masonry section, including the spillway, is approximately 1000 metres

Selection of the Site

3·3 Geology, hydraulic considerations, availability of construction materials and economic utilisation of waters are the main issues to be studied in the selection of a site for a dam. Several sites were investigated for building a dam in connection with a joint scheme between the States of Hyderabad and Madras Of these, only the Yeleshwaram and Nandikonda sites were competitive and were investigated in detail

The gorge at Yeleshwaram village is 445 m. wide with a flat bed and high precipitous hills on either side The nature of the rock in the river bed is composed of a sheet of unfissured granitoid gneiss There are no saddles for the location of surplus gates and the width of the river is not adequate for a power house and for the location of surplus works, and the site requires high flood gates. Being a narrow gorge, there are difficulties in the diversion of the river for building a coffer dam during

construction, as the river passes through the narrow deep gorge in the monsoon season. The dam needed to be high for the off-take of the canals which had to pass through long tunnels before the water could be utilised for irrigation. A high dam was proposed to be built which was costly. Mainly, the following factors were considered in the selection of the final site :—

(i) Facilities for canal off-take at a good commandable level

(ii) Good rocks at reasonable and workable depths for the foundations

(iii) Stable and good abutments ; facilities for surplusing large floods and diversion of flows during the construction

(iv) Availability of construction materials such as good stone, sand and earth for surki, at reasonable distances ; and

(v) Good location for power generation

Keeping these factors in view, the site at Yeleshwaram was shelved in favour of the site at Nandikonda.

The Nandikonda Site

3.4 Nandikonda site is situated between the confluence of the Dindi river and Chintalapalam, where the river opens out and satisfies the conditions stipulated above. The lowest bed level of the river at the dam site is 72 m. and the average bed level is 75 m. The catchment area at the site of the dam is 2,07,200 sq.km. with a maximum discharge of 42450 cumecs., the observed minimum discharge being 2.83 cu. mecs. The off-take level for the left and right canals is 149.05 m. about 74 m. above the average bed level and water has to be stored for a depth of 30.48 m. over the offtake level. The high offtake level gives a sufficient storage capacity for silting and a high head for the generation of power.

Geology

3.5 The Nandikonda site which was finally selected for the dam had been inspected in 1951 by a team of eminent geologists, the late Cpt. Munn and the late Mr. C. Mahadevan. They reported that during aeons of years the river had cut through a gneissic knoll overlaid by quartzites. In the northern cliff on the left bank, gneiss is exposed at 124 95 m. and on the southern cliff on the right bank, the gneiss is exposed at 109.73 m. Above the levels of gneiss rocks on the flanks are fresh quartzites, interposed by beds of shales The original continental surface upon which the sediments are laid, was worn away to form the gap through which the river now flows. These might once have been the sides of a sloping gneissic hill. The crystalline rocks, after exposure to atmospheric agencies through millions of years, have presented a de-

composed surface. When the cliffs were stripped a few metres, strong, compact and undecomposed rock was exposed. The phenomenon of decomposition of rock was slightly greater on the right bank of the river. The sealing of the bed joints and fissures of quartzites on the flnaks required all the precautions the engineering skill could devise (See Fig. 2 and Fig 3)

Bed Rocks

3 6 At the site finally selected for the dam construction, the bed of the river consists of massive and fresh granite gneisses of the peninsular gneissic complex and the flanks are the quartzites and shales of the Srisailam stage of the Cuddapah system The masonry dam is founded on granite rocks from blocks 6 to 69, while blocks 1 to 5 on the left flank and blocks 70 to 79 on the right flank are founded on fresh quartzites

On the right abutment of the dam, the granite gneisses are overlain unconformably by an approximately 73 metres thick sequence of quartzites and shales at an elevation of 109 7 metres (360 feet). Near the axis of the dam on the left abutment, the separation plane between the granite-gneisses and the sedimentaries occurs at a level of 124 metres (410 feet), the thickness of the overlaying quartzites and shales being 58 metres Near the bridge site, located about 884 metres downstream of the dam axis, the junction between the granite-gneisses and the sedimentaries occurs at a level of 85.3 metres on the left bank and at a level of 70 1 metres on the right flank A few dolerite dykes, which are intrusive into the granite-gneisses, are also exposed at the dam site These dykes extend only up to the contact between the crystallines and the sedimentaries, thereby indicating their pre-Cuddapah age

The granite-gneisses exposed at the dam site are grey in colour, coarse grained and massive. They range in composition from hornblende granites to granodiorites. The foliation of the granite gneisses is generally not pronounced, but where discernible it strikes in N 40°W—S 40°E direction, with almost vertical dips

The quartzites occurring near the top of the abutments are thick bedded and massive, fine to medium grained, hard and compact, with occasional intercalations of sandy shale, while those occurring near the unconformity are generally coarse grained, gritty and feldsparic. The top quartzites are grey to white in colour and the intercalated shales are commonly grey, buff, or black, while occasionally they are light pink to red The grey and buff shales are soft, whereas the black shales are mostly siliceous and hard and grade into slates. The black shales contain pyrites, both as lumps and as fine disseminations Carbonaceous material is also present in traces in the black shales

The quartzites exhibit oscillation ripple marks and cross-bedding The shales of both grey and black types have a gradational relationship

with the quartzites with which they alternate. They also exhibit interfingering with the quartzites and pinch out laterally within short distances. These features clearly bring out the shallow water environment of deposition. There is no evidence to indicate any structural disturbance of the bedrock near the contact of the sedimentaries and the crystallines.

But for the presence of a major shear zone in the river bed and a fault zone in the left abutment, the granite-gneisses at the dam site are, by and large, structurally undisturbed Most of the joints in the granite—gneisses are either tight at the surface or become tight at shallow depths. The strike of nearly 80 per cent of the joints in the granite-gneisses lies between N60°W—S60°E and N40°E—S40°W directions. These joints are vertical and lie more or less parallel to the foliation of the gneisses.

The quartzites and shales dip at an angle 3° to 5° towards the downstream side Besides the bedding of joints, which are prominently developed in these bedrock units, there are two sets of prominent, mutually perpendicular, vertical joints. By virtue of these joints, the quartzites generally break into rectangular blocks. Minor faults, with the throw rarely exceeding 0 60 to 0.91 m., are observed at a few places in the quartzites.

Structural Properties of Bed Rocks

3.7 The physical and engineering properties of bedrocks of the dam site are listed below :

Description of bedrock	Density	Absorption %	Compressive strength (Tonnes per Sq. m.)	Youngs' Modulus of Elasticity (kg. / Sq. cm. × 10^6
Hornblende Granite gneiss	2.68 to 2 71	<0 5	3456 to 13,386	..
Massive quartzites	2.60 to 2.67	0.68	3620 to 8968	0 77
Buff shales	2.20	..	2679	..
Black shales	2.65	<1.0	1728 to 3456	0.12 to 0 14

Weathering and Foundation Stripping

3 8 The weathering of granite-gneisses in the river bed was found to be limited to relatively shallow depths, ranging from 0.6 to 4.6 m On the other hand, the granite-gneisses in the abutments were weathered up to a considerable depth, particularly near the junction of the crystallines and the sedimentaries Thus, in the left abutment, the depth of weathering ranged from 6 to 12 m , while in the right abutment this extended upto 18m. Generally, the depth of weathering in the quartzites varied from 1.5 to 6m., the greater depth of weathering occurring in the right abutment

Explorations revealed that sedimentaries directly overlie the fresh granite-gneisses without any intervening zone of weathering, and that they were confined to the reach of the dam alignment lying to the left of ch 88+35 (RD 2695 m) in the left abutment and to the right of ch.126+60 (RD 3861 m) in the right abutment. At the above-mentioned chainages, two vertical, transverse faces, 21 to 24 m in height, were excavated in the abutments The dam was founded on fresh granite-gneisses from blocks 6 to 70 and on quartzites for the remaining portion

Important Foundation Features

3 9 The foundations of the left abutment from blocks 1 to 5 consist of flat bedded quartzites and slaty shales for a depth varying from 21 to 24 m overlying the granites At the contraction joint between blocks 5 and 6, a vertical section of quartzites and shales was exposed during excavation. The strata of sedimentary formation exposed over granite rocks is as follows .

Classification of rocks	Elevation	Depth
(*a*) Granite rock	124.97 to 125.58 m.	0 61 m.
(*b*) Quartzites and shales	125 58 to 128 63 m.	3 05 m.
(*c*) Slaty shales with intercalations of quartzites	128 63 to 135 63 m	7 00 m.
(*d*) Thin bedded shales and quartzites	135 63 to 143 26 m	7 63 m.
(*e*) Massive quartzites	143 26 to 155 76 m	12 50 m.

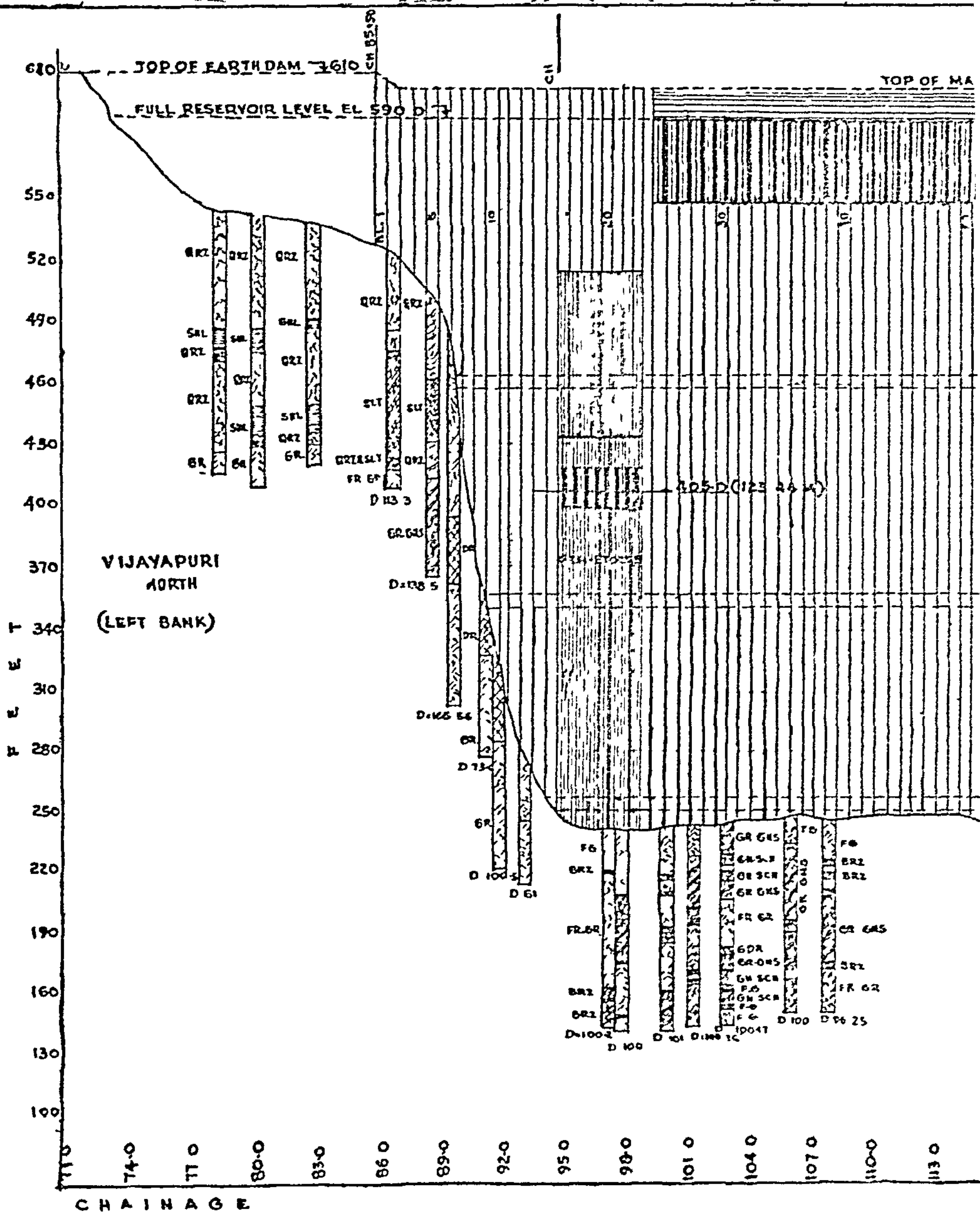
3.10 The thickness of massive quartzites is varying from 7.63 m to 12 19 m. The massive quartzites are traversed by numerous joints which could take effective grout The slaty shales contain thin soft material

along the joint planes. They were local and continuous. There was no definite indication of softer material running across the foundation of the dam.

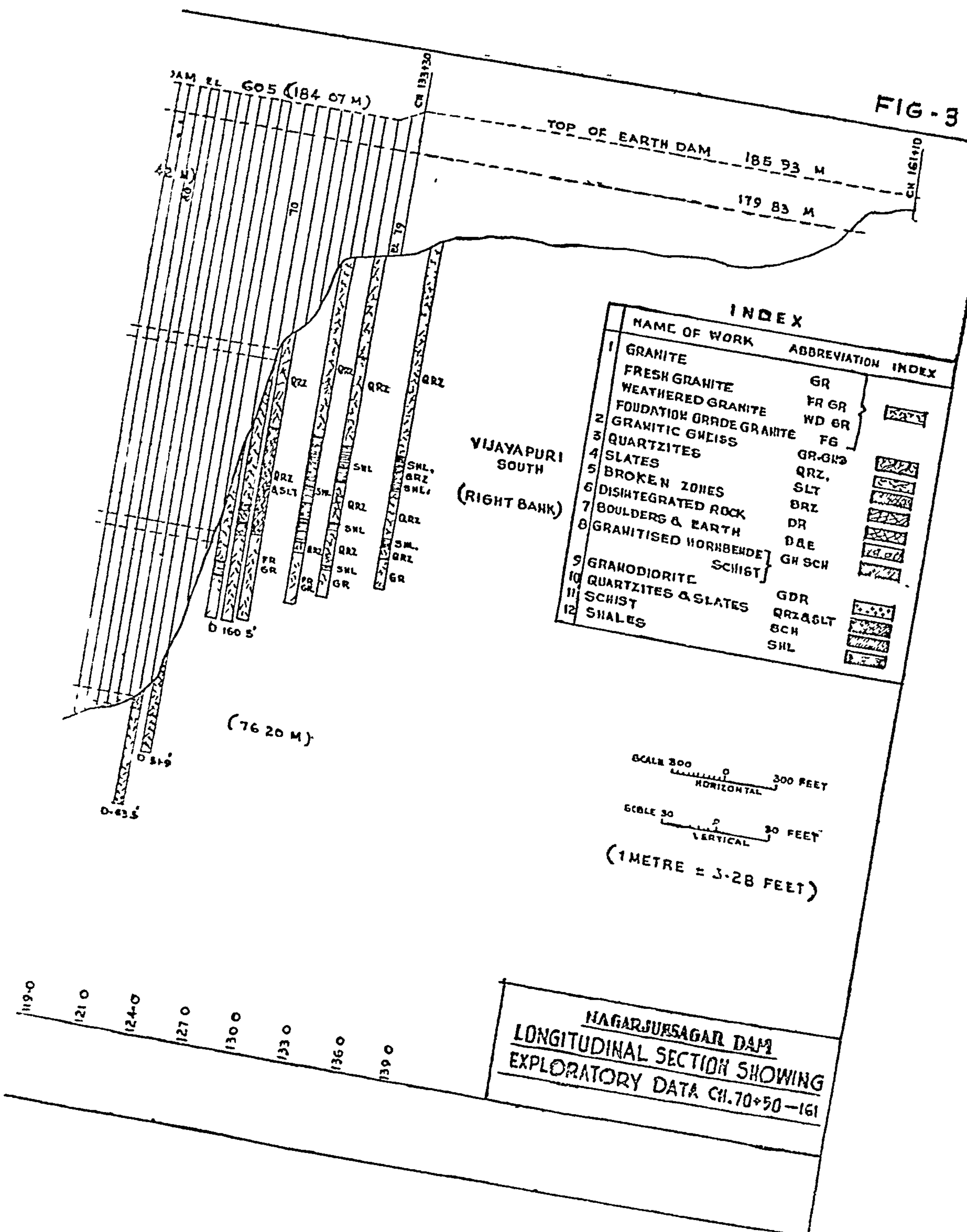
3.11 At the abutments of the masonry dam, it was a great problem whether to found the dam on the quartzites or shales or to excavate these rocks upto the level of granite rock. In order to decide this issue, a number of holes were drilled at close intervals both along the axis as well as along the downstream toe line. This became necessary in order to find out the thickness of various formations, to determine the soundness of rocks and to assess the permeability. These holes were drilled through flat bedded formations and also to some depth into the granite rocks. The exposed face excavation at the vertical ledge in block 5 showed numerous joints in the quartzites. The quartzites and shales as exposed at foundation level are fresh and acceptable for founding the dam. If the excavation were to be taken down to granite level of 124.97 m., it would have involved a rock cutting of nearly 30.48 m. in quartzites and shales and back filling with masonry which would have been expensive. It was verified that the strength of quartzites and slaty shales was sufficient for the incoming loads. The permeability was high in quartzites and very low in shales. After a thorough geological study, it was decided to found the dam on the sedimentary rocks with intensive grouting extending into the underlying granite rocks below. Percolation tests conducted showed losses from 31.82 to 72.74 litres per minute in quartzites and 0 to 13.63 litres per minute in shales. The tests indicated that it would be possible to seal the joints in the quartzites effectively.

Mapping the Foundations

3.12 The entire area of foundations for the masonry and the earth dam was mapped by a geologist. For this purpose, right from the beginning of the construction, the services of an engineering geologist were taken from the Geological Survey of India. Mr. A. V. Chalapathi Rao had the privilege of serving the project right from the beginning. He mapped the entire areas. The foundations were covered only after the areas were passed by the geologist. This was necessary in order to make sure that the dam was founded on sound foundations. The geologist had also to suggest remedial measures for the treatment of weak zones. Regular drawings were prepared which also indicated strikes, dips and fault zones. Grout pipes were fixed in advance in faults and other needed points before covering the areas. Important and difficult geological formations to be treated were also examined by senior engineering geological experts and their advice was taken for the treatment. Mr. Hamza Ali and Mr. Balasundaram were the senior geologists whose expertise was availed of in tackling difficult geological formations.



TOP OF EARTH DAM 610
FULL RESERVOIR LEVEL EL 590
TOP OF MA
VIJAYAPURI
NORTH
(LEFT BANK)
FEET
620
550
520
490
460
430
400
370
340
310
280
250
220
190
160
130
100
71.0
74.0
77.0
80.0
83.0
86.0
89.0
92.0
95.0
98.0
101.0
104.0
107.0
110.0
113.0
CHAINAGE


FIG - 3
DAM EL 605 (184 07 M)
TOP OF EARTH DAM 185 93 M
179 83 M
CH 133+30
CH 161+10
VIJAYAPURI SOUTH
(RIGHT BANK)
(76 20 M)
D 160 5'
D 51-9'
D-63 5'
INDEX
NAME OF WORK ABBREVIATION INDEX
1 GRANITE GR
FRESH GRANITE FR GR
WEATHERED GRANITE WD GR
FOUDATION GRADE GRANITE FG
2 GRANITIC GNEISS GR-GNS
3 QUARTZITES QRZ.
4 SLATES SLT
5 BROKEN ZONES BRZ
6 DISINTEGRATED ROCK DR
7 BOULDERS & EARTH B&E
8 GRANITISED HORNBENDE SCHIST GN SCH
9 GRANODIORITE GDR
10 QUARTZITES & SLATES QRZ&SLT
11 SCHIST SCH
12 SHALES SHL
SCALE 300 0 300 FEET HORIZONTAL
SCALE 30 0 30 FEET VERTICAL
(1 METRE = 3.28 FEET)
119.0
121.0
124.0
127.0
130.0
133.0
136.0
139.0
NAGARJUNSAGAR DAM
LONGITUDINAL SECTION SHOWING
EXPLORATORY DATA CH.70+50—161

Preparation of Foundations

3.13 For the preparation of the foundations, blasting of weathered rocks was restricted when they were overlying within 0.60 m. of sound strata. This 0 60 m. of rock was removed by wedging and barring Wedging and barring is a process by which rocks are excavated without blasting In the final stage of the foundation preparation, even light charges shatter foundations and so the last 0.60 m. is removed by this method. In this process chisels, hammers and crowbars are used For breaking big boulders and hard strata, line drilling at intervals of 15 to 30 cm. is done to the required depth and the rock is broken by inserting round chisels in these holes and hitting these with 6 kg hammers. The process is costly, as it has to be done manually with crowbars and hammers and without using explosives *Pneumatic tools like rippers and demolishing tools* were also used for this process. This method ensured that sound foundation rock is not disturbed at the final foundation level. The wedging and barring is twice as costly as blasting The data for excavation in rocks by wedging and barring was Rs 18 70 per cu m. as against Rs. 8.70 per cu m. for rocks requiring blasting as per rates in 1956 and 1957. This work was done departmentally.

3 14 After striking the required strata, the final foundation was carefully prepared by removing all slabby or drummy rock With 0.90 kg hammers, the foundation surface was knocked and the sounds were observed Unless the rock gave a ringing sound it was considered to be having loose mass which was removed by chisel and hammer Weathered and decomposed rocks were removed by chiselling and were thoroughly cleaned. All the smooth or polished surfaces were roughened. The surface was freed from steep angular stones and was chamfered approximately 45°.

3 15 The final foundation preparation was not done earlier than a week ahead of construction of masonry on it, as exposure for too long a time would lead to cracks at weak places due to temperature variations. Finally, the foundation was thoroughly cleaned of all loose particles, dirt, oil or grease, by the use of stiff brooms, wire brushes or jets of air and water under pressure or sand blasting. In the absence of sand blasting, one line dressing of rock, followed by thorough washing with wire brushes, gave the same effect The jet of water used should not be of less than 1.4 kg per sq. cm pressure Washing and scrubbing was continued until water collecting in pools was clear and free from dirt In the final cleaning process, the wash water was removed by sponges

All the holes were filled up with cement concrete and masonry was laid directly over foundations

Before the final preparation of the foundations, grouting was carried out to seal the cracks in rock joints.

Foundation Treatment

3.16 Foundation treatment is broadly classified under two stages :

(i) Excavation operations consisting of removal of all loose material above sound and acceptable rock formation.

(ii) Subsequent operations consisting of pressure grouting and drainage treatment.

The depth of the final foundation of the dam was determined after exploration of sub-surface formation by means of diamond drill holes extending upto 30 m. depth below the bed of the river. Percolation tests were made in the holes drilled by pumping water under pressure for testing the impermeability of the foundation. The design of the foundation excavation and the grouting treatment were based on the data obtained from examination of rock cores, a thorough study of the geological features and the percolation test results.

3.17 Foundation treatment work started after completing the excavation to the acceptable rock level. The treatment comprised drilling and washing of holes and grouting operations which were started only after the blasting operations were completed within 16 m of the area to be treated. Even in hard, massive and monolithic foundations, local defective zones like veins and fissures existed The grout holes were so located as to intercept these defective zones at different depths from the foundation surface for the purpose of washing the soft and decomposed material and for subsequent grouting. When narrow veins containing clay and soft material were met with, they were widened out and deepened with crowbars and pick-axes till the hard surface was met with at the bottom or till the joints became thin. After this operation, inclined grout holes were drilled to intercept these zones at lower elevations. The soft material in the veins was washed out using compressed air and water, and then grouted.

The sequence of operations followed in the grouting of the foundations is described below

(*a*) Low pressure or consolidation grouting done with shallow drill holes designated "B holes"

(*b*) High pressure or curtain grouting done with "A holes"

(*c*) Drainage of foundation is carried out with "D holes"

The grout holes were drilled by percussion action with wagon drills operated by compressed air using tungsten carbide bits. Three important operations were carried out before the grouting work started They were washing of drill holes, pressure washing and pressure testing.

Low Pressure Grouting

3.18 Low pressure grouting is for treating the surface layers at shallow depths to provide a general consolidation of the surface rock and to fill and seal major surface seams, joints and crevices This operation, known as consolidation grouting, precedes raising the foundation masonry For the consolidation grouting of the Nagarajunasagar dam, holes were drilled 9 m. deep, at 6 m centres in four rows parallel to the axis of the dam, the spacing between adjacent rows being about 6 m Holes in each row were staggered with those in the adjacent row Holes were drilled at closer intervals where fissures, fault zones and crushed zones were located. When sheet rock was met with, holes were drilled at 6 m centres in the first and second rows and 12 m centres in the third row and the fourth row was omitted These holes were grouted in the first stage so that greater penetration and more effective sealing of fine seams could be secured by subsequent application of high pressure grout in the course of curtain grouting These holes, known as "B holes", vary from 50 mm. to 62 mm. diameter. They are drilled normal to the surface unless it is desired to intercept some seams and joints at an angle The drilling is carried out to a depth sufficient to intercept major crevices and fissures Grouting pressures varied from 2 8 to 3.5 kg. per sq. cm in quartzite zones and 5 25 to 7. kg per sq cm in good granite rocks. In sedimentary formations like quartzite, holes were put in full width and length of the blocks and where joints and bad portions existed additional holes were drilled and grouted. Blanket grouting of the rock in front of the dam also was done for 15 to 30 m width in the same manner as for the consolidation grouting The water-cement ratio of the grout mix varied from a thin mix of one cement and ten water to a thick mix of one cement and half water by volume For a cut off trench along and under the base of the earth dam, a single row of low pressure ' B ' holes was drilled 9 m deep at 6 m intervals At faulty zones, the holes were drilled at closer intervals

High Pressure Grouting

3.19 High pressure grouting was carried out through a single row of holes (" A holes "). This line of drilling was done along the upstream edge of the foundation gallery. This is known as a grout curtain and forms the principal barrier against percolation through foundations and serves as a curtain to arrest uplift pressures High pressure grouting was carried out after the masonry had been raised to nearly 40 m above the foundation level. As curtain grouting had to be done under high pressures varying from 7 to 21 kg per sq cm the weight of masonry over the foundation kept the movement of surface layers of foundation from disturbance and heaving under high pressure of grouting The 'A' holes, 48 mm. dia were drilled through the foundation gallery at 3 m intervals for

the entire masonry dam and at closer intervals of 0.75 to 1 5 m. in faulty zones. Drainage holes were put along the down-stream of the grout curtain in order to release the uplift pressure of water that passes the grout curtain.

Washing and Pressure Testing

3.20 Before the pressure grouting of each stage of any hole was begun, the hole was thoroughly washed under pressure and pressure tested. In the case of percussion drilling, drill cuttings and slurry were removed before pressure testing by applying water and air to the bottom of the hole and returning the wash water through the hole to the surface. All intersected rock seams and crevices containing clay or other washable material were washed with air and water under pressure to remove as much of these materials as possible. Whenever possible such materials were ejected from one or more holes by introducing water and air under pressure into an adjacent hole. Special care was taken to see that the washing pressure never exceeded the maximum grouting pressure. All grout holes were tested with clean water at a pressure upto the required grouting pressure. All holes sufficiently tight to build up the maximum required pressure were washed at the required pressure and the washing was continued as long as there was any increase in the intake of water. Such increase indicated that fractures were being opened by the washing operation Holes in which the required pressure could not be reached, were washed as long as there was any increase in the rate of flow or drop in pressure when the pump was delivering the required flow. Open holes in which no pressure could be built up were washed at least for five minutes or more till fracture filling was observed which could be determined by the escape of muddy and coloured water through the surface openings or through other grout holes

Grout Pressure and Grouting

3.21 Grout pressures were kept as high as practicable but controlled to avoid disturbance of rock structure. In general, for consolidation grouting, grout pressures varied from 3.5 to 7 kg. per sq. cm. and for curtain grouting the maximum pressures were 21 kg. per sq. cm. Grout pressures varied to suit the depth of the holes, the distance from the exposed rock surface, and the character of the rock with reference to the open joints, seams etc. The highest possible pressure consistent with the safety of the strata, speedy work and the largest possible coverage, as determined by pressure testing and check levelling during grouting, were used. In some cases where deemed necessary, the upper seams were grouted in advance of the regular programme in order to permit increased pressure on the lower seams. In general, stage grouting was adopted. Depending

upon the field conditions, different grout pressures were adopted for grouting different sections of grout holes. This was achieved by attaching a packer to the end of a grout supply pipe. The packer consisted of expansible rings of rubber The packers were designed so that they could be expanded to seal the drill holes at the specified elevation and, when expanded, should be capable of withstanding water pressure without leakage whatsoever. The water pressure was kept equal to the maximum grout pressure to be used For doing high pressure grouting, the first holes were spaced at 6 m intervals and were grouted before intermediate holes were drilled and grouted. The spacing of the intermediate holes depended on the grouting results shown by the previous holes to obtain a continuous grout curtain.

3 22 To test the efficiency and penetration of grout in the grout curtain, holes were drilled in the plane of the grout curtain after deep grouting operations were completed. These holes were tested under a water pressure equal to the pressure adopted for high pressure grouting and the amount and rate of leakage in each hole was measured. If any hole showed excess leakage, it was grouted under pressure. This operation was followed by a new test hole which was tested under pressure in the same manner

Grout Records of Left Earth Dam

3 23 Holes were drilled in the centre line of the upstream cut off trench at 6 m intervals in the first instance Depending upon the test results, intermediate holes were drilled wherever necessary. The depth of the holes varied from 18 to 24 m and the total depth drilled was 4,263 m. The pressure applied varied from 2 1 to 5 25 kg. per sq. cm. and the total quantity of cement consumed amounted to 17,724 bags (886 tonnes). The mix varied from one cement to ten water to one cement to four water measured by volume. The period of grouting extended from June 20 1958 to April 7, 1971 and the consumption of grout per linear metre of hole worked out to 4.19 bags (210 kg. per metre).

Grout Records of Right Earth Dam

3 24 The method of drilling and grouting adopted for the right earth dam was the same as for the left earth dam. The total number of holes which were drilled in the front cut off trench was 309 with a total length of 3,143m. The total consumption of grout was 7,271 bags (363.5 tonnes). The period of drilling and grouting operations extended from January 2, 1964 to May 31, 1973. The consumption of cement for linear metre of hole worked out to 2.38 bags (119 kg.) per m.

Grout Records of the Main Dam—Consolidation Grouting

3.25 For consolidation grouting three rows of holes were drilled on the upstream at 6 m. intervals to an average depth of 9 m. In addition to this the seams and crevices were treated with additional holes. The total drilled, works out to 24,909 m. grouted with 17,952 bags (897.50 tonnes) of cement. The average intake of grout per metre run works out to 0 720 bags (36 kg. per metre). The following are the blockwise details:

DETAILS OF CONSOLIDATION GROUTING

Block Number	Average level of foundation rock in metres	Metres Grouted	Cement consumption in bags	Average intake of Cement per linear metre in kg.	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
1	155 34	155.44	467.75	153.00	Quartzite rock
2	153 81	423 35	533.50	64.00	
3.	151 16	434 94	885.50	103.30	
4.	149 15	597.40	1988 97	175.00	
5.	149 03	206 18	170.75	42.00	
6.	124 96	149.48	54.12	111.70	Granite rock
7.	100.00	111.21	299.37	13.60	
8	95 13	87.89	286.00	16.50	
9	94 88	358.43	130.12	18.33	
10.	92 40	177.68	61.75	17 60	
11	82.80	204.20	15.87	42.70	
12	80.10	82.29	2.25	1.50	
13.	75.91	115.82	1.00	0.40	
14.	72 35	171.59	4.00	1.20	
15.	70.70	255.21	19 56	4.00	
16.	70.28	152 70	2 75	0.90	
17.	69.75	109.30	174.50	81.60	
18	69.60	301 13	166.50	28.00	
19.	68 89	495.59	436.50	44.80	
20.	69 70	359.04	303.50	42.70	
21.	68.93	368.83	324 30	44.60	
22	68.58	269.18	284.62	53.60	
23.	69.27	73.30	121 50	84.20	
24.	69.41	90.88	49.12	26.90	

(1)	(2)	(3)	(4)	(5)	(6)
25.	69.71	152.40	30.12	16.70	Granite rock
26.	69.94	186 82	62.87	16.50	
27	70.70	136.84	21.50	8.00	
28.	72.11	447.14	307.25	34.80	
29.	71.52	273.70	277.50	46.30	
30.	71.67	167.64	14.50	4.40	
31.	73.13	188.89	9.75	2.60	
32	74.18	124.97	3.75	1.50	
33.	73.49	134.41	23.00	8.70	
34	75 03	170.07	19 81	6 00	
35	74 04	194 07	115 62	30 90	
36.	73 54	229.81	18.18	4.00	
37.	73 13	198.42	15.50	3.90	
38	72 59	149.35	11.47	3 70	
39.	86.95	103.63	11.54	5.60	
40.	71 92	210 91	116.12	27 00	
41.	72.25	96.92	9.12	4 70	
42	72 50	137.76	25 75	9.40	
43.	72 72	82 30	25.75	15.80	
44.	72 91	110 22	32 50	13 70	
45.	72 95	132 58	20 00	7 60	
46.	72 95	221 27	40 50	9.50	
47	73.75	131 16	45.54	17 60	
48.	73 13	49 36	65.25	3.40	
49.	73 34	96.92	97 25	4 10	
50	73 08	90 52	10 91	6 20	
51.	73.14	191.10	62 25	18 16	
52.	73.49	163.24	97 25	30.00	
53.	73 62	77 71	4 25	2.70	
54.	73.50	83 81	88.60	53.40	
55.	70 57	196.58	41 25	10 60	
56	70.14	476 08	290.00	30 80	
57	69 00	334.96	219 12	33 20	
58.	65 91	761 05	754.47	50.30	
59.	67.02	584 90	443.62	38 40	
60	67 11	190.87	42.50	11.30	
61	69 55	228.80	51.57	10 90	
62	71 68	143.25	49 87	17.60	
63	72.97	238 34	108.50	22.10	
64	74.49	118 87	15.75	6.70	
65.	75.71	303 56	120 37	21.10	

(1)	(2)	(3)	(4)	(5)	(6)
66.	77.71	425.15	212.62	25.40	Granite rock
67.	87.32	376.72	51.87	0.70	
68.	93.81	532.37	158.00	15.10	
69.	106.80	254.20	78.00	15.50	
70.	110.80	73.15	18.75	13.00	Quartzite rock.
71.	138.37	18.28	49.80	13.80	
72.	139.59	230.44	89.00	19.60	
73.	142.00	561.58	291.25	28.00	
74.	143.55	584.30	380.75	33.00	
75.	144 15	487.78	160.00	16.70	
76.	144.57	210.30	1422.75	343.00	
77.	144.57	116.14	2420.25	654.00	
78.	144.37	164.59	1665.00	51.40	
79.	144.00	310.31	4.65	7.80	
	Total	24,908.82	17,951.53	36.70	Average.

Drainage Hole Records

3.26 One hundred mm. diameter drainage holes were put at 3 metre intervals on the downstream of the grout curtain. These holes were meant to release the uplift pressure of water that would pass through the grout curtain. These holes were generally 12 metres in depth and were drilled through the foundation gallery. The following are the details of the drainage holes blockwise:—

DETAILS OF DRAINAGE HOLES

Block Number (1)	Average depth of drainage hole in metres (2)	Remarks (3)
1.	11.70	Quartzite rock.
2.	11.10	
3.	12.60	
4.	11.10	
5.	23.10	
6.	8.70	

(1)	(2)	(3)
7.	13.50	Granite rock
8.	18.30	
9	12.60	
10	18.00	
11.	15.00	
12	21.00	
13	12.00	
14.	18 00	
15.	15 00	
16	18 30	
17.	24 00	
18.	18.30	
19.	24 00	
20.	24.00	
21.	24 00	
22.	24 00	
23	12.30	
24.	24 00	
25.	12 60	
26.	18.00	
27.	12 00	
28.	24 00	
29.	18 00	
30	16.70	
31.	11 40	
32	18 00	
33.	12 00	
34.	18 00	
35.	12 00	
36.	12 00	
37.	18.00	
38	18.00	
39	15 90	
40	18 00	
41	16 50	
42	18.00	
43	18.00	
44	18 00	
45.	16.70	
46	11.40	

(1)	(2)	(3)
47.	18 00	Granite rock
48.	18.00	
49	18.00	
50.	12.00	
51.	18.00	
52	12.00	
53.	18.00	
54	12 00	
55.	18 00	
56.	12.00	
57.	18 00	
58.	7.50	
59.	18.30	
60.	12.30	
61.	18.00	
62.	15.30	
63.	18.00	
64	15.00	
65.	18.00	
66.	12 90	
67.	24 00	
68.	21.00	
69.	13.50	
70.	17.40	Quartzite rock
71	6 30	
72.	10 50	
73.	10.50	
74.	9.90	
75.	12.00	
76.	9.90	
77.	10.80	
78.	9.60	
79.	11.10	

Grout Curtain Records

3 27 For high pressure grouting to form a grout curtain, the drilling operations were conducted through the drainage gallery. The depth of holes was taken generally to 45 m. Before covering the foundation, the pipes were put from bed rock to gallery floor. After raising the dam to a considerable level to serve as counter weight, holes were drilled

and grouted under high pressure through the pipes. For determining the depth of holes the following formula was used :

$$d=1/3\ h+c$$

Where d is depth of hole in metres

h is height of the dam above hole in metres

c is the constant from 7.5 to 22 5

Pressures varied from 7 kg. to 35 kg per sq. cm The total depth drilled was 1,937 metres treated with 6,355 bags (317.7 tonnes) of cement. The average consumption of grout per linear metre worked out to 0.412 bag (20 6 kg. per metre). The blockwise details are given below :

DETAILS OF CURTAIN GROUTING

Block Number	Total Metres drilled in each block	Total cement consumption in each block in bags	Average intake of cement Kg per metre	Remarks
(1)	(2)	(3)	(4)	(5)
1.	152 40	122 25	37.10	Quartzite rock
2	276.72	121.25	22.10	
3.	236 18	77.63	16 50	
4.	231.82	55 00	10.30	
5	79.84	19.75	12 30	
6.	138 28	15.75	5 70	
7.	140 08	25.50	9 00	Granite rock
8.	80 14	14 75	9.20	
9.	79.24	4 00	2 40	
10.	80 76	15 50	9 50	
11.	48.76	9.00	9 20	
12.	99.05	9 00	4 30	
13.	182 88	14 50	4 00	
14	95 09	24 50	13 00	
15.	117 04	13.00	5.60	
16	93 57	17.75	9.50	
17	231.22	27.38	5 90	
18	286 59	62 58	11 00	
19	268 22	42 71	7.90	
20	314 84	131 38	20.90	
21.	469.07	247 63	26.50	

(1)	(2)	(3)	(4)	(5)
22.	355.50	184.13	26.00	Granite rock
23.	301 89	153.88	26.50	
24.	351.52	169 25	24.20	
25.	183 28	29.75	8.60	
26	182 88	216.50	5.90	
27.	145.68	28 29	9.60	
28.	189.07	27.50	7.20	
29.	198.27	78.50	19.90	
30.	216.99	227.25	52.60	
31.	137.56	42.5	15 50	
32	137 56	21.5	7.90	
33.	137.56	64.08	23.40	
34.	45.72	2.25	2.40	
35.	91.44	5.25	3.00	
36.	45.72	1 00	1.10	
37.	91.44	2.75	1.40	
38.	45.72	10.00	1.10	
39	96.62	6.25	3.10	
40.	45.72	1.00	1.10	
41	91 44	8.00	4.80	
42.	45.72	1.25	1.30	
43	91.44	2.25	1.30	
44	45.72	5.00	5 40	
45.	91.44	17.50	8.60	
46.	45.72	1.50	1.60	
47	91.44	13.38	7.40	
48.	45.72	0.75	7.40	
49.	91.44	3.50	2.00	
50.	45.72	11.75	12 90	
51	96.47	14 00	7.10	
52.	45 72	2.88	3.10	
53	91.44	20.75	11.10	
54.	45.72	9.00	9.60	
55	207.26	51.38	12.80	
56.	228 60	139.50	30.40	
57.	257.04	371.50	72.30	-
58	259.08	620.17	119.80	
59	231.64	333 13	72 20	
60.	228 60	270.33	59.40	
61.	258.11	536.38	103.90	
62	203.21	191.08	47.10	

(1)	(2)	(3)	(4)	(5)
63.	173 85	44 5	14 20	Granite rock
64.	202 88	84 88	20 90	
65.	229 81	381 50	83.50	
66	134.11	37 75	13 80	
67.	125 46	51 75	20.50	
68.	120.48	53 75	22.20	
69.	139.89	29.75	10.60	
70.	166.30	51 50	15.50	Quartzite rock
71.	236.82	47.00	9 90	
72	271.51	95.25	27 80	
73	234 38	54.25	11 50	
74	241 48	33 25	6 90	
75	245 97	40 25	8 00	
76.	284 38	88.75	15.66	
77.	271.57	136.15	23.06	
78.	291.99	73.00	12 50	
79.	188 36	85 00	22.00	
	13,093.23	6,355.82	24 40 Average	

Foundation Problems

3.28 The crystalline rocks in the bed of the river presented no difficulties The exposed gneisses were exceptionally free from fissures. However, a deep vein had to be treated in block 14 which had to be opened upto 59.77 m. level about 16.45 m. below the bed level of the river. Generally small fissures and veins were opened to a depth equal to twice their width and back filled up with concrete, and grout pipes were provided at 1.2 to 3.0 m. intervals depending upon the nature of the opening for enabling effective contact grouting. Considering these points, the choice of the site in this respect was very appropriate

The depth of beds of sedimentary quartzites and shales overlying gneissic rock is 27.4 m on the left flank and 41.1 m. on the right flank. On the flanks the dam was given a penetration of 29.3 m into the quartzite formations. In the contact planes, dowel bars and grout condulets were inserted wherever necessary and grouted.

Major fault zones and crushed zones which required extensive treatment are described in the following paragraphs giving details of the treatment effected:

(*a*) Fault zones in blocks 7, 8 and 9,

(b) Dolerite dyke zone in blocks 18 to 23
(c) Crushed zone in block 55.
(d) Joints in blocks 70 A and 71.

Fault zone in Blocks 7, 8 *and* 9

3.29 The fault zone in blocks 7, 8 and 9 was not originally detected during the exploratory stage, but discovered during the final excavation as a wide soft zone dipping towards the upstream, existing below a mound of fresh granite rock. It was seen from the bore hole data that the thickness of fresh granite above the soft zone is of the order of 18 to 30 m near axis The weathered and crushed rock also has an upstream dip and is exposed up to 42.7 m. downstream of axis in blocks 7 and 8. Five additional diamond drill holes were drilled from top of the mound to determine the extent of the fault zone and to decide on the treatment to be given. It was confirmed that the fault plane extends in N 40° E and dips at 28° in S 58° W towards the upstream. The fault zone was exposed between elevations 51.8 and 103 m. The fault zone consists of highly weathered and crushed granite, varying in thickness from 1.2 to 4.9 m. The granite-gneisses, close to the hanging wall of the fault, were highly fractured and jointed in contrast to the massive granite-gneisses occurring on the oblique-dip-slip type, with the maximum amount of the throw not exceeding three metres. The fault zone was wider in block 8 and narrows down to about 1 m. and 0 3 m as we follow it into block 7. The following treatment was given in order to safeguard the foundations against the possibility of settlement :

(i) The thickness of the fresh rock overlying the fault zone is kept at not less than 7.5 m. at any place.

(ii) The mound in blocks 7 and 8 was thoroughly consolidated by grouting with grout holes extending below the fault zone.

(iii) The fault zone was excavated inside by removing the weathered and soft material by excavating 3 m. deep and back-filled with cement concrete of 19 mm. aggregate.

(iv) Holes were drilled from top of the mound as well as angle holes from the slope of the mound and washing of the fault zone was done at a number of points. As the excavation in the fault zone was carried out till hard strata were reached inside, very little material was washed out through these holes, excepting the holes along the axis, where the reddish earth filled joints were washed out

(v) Contact grouting was done where concrete was laid butting the vertical surface of the rocks by providing condulet cups

where separation was expected between the old and new works due to shrinkage of concrete These condulet pipes, consisting of 12 mm. G.I. pipes, were provided with a cup at the open end. The other end was connected to a main pipe of 25 mm diameter G I. pipe and grout was sent through the main pipeline

(vi) Above the fault zone level the scales of weathered rock sticking to the face of the granite mound were removed by wedging and barring and the surface roughened by chiselling before the masonry was laid. A 0.9 m. thick masonry abutting rock face was done in pneumatic vibrated masonry in order to get thorough compaction and bond at the contact planes.

(vii) 25 mm diameter anchor bars were provided on the vertical and sloping face of the rock mound at 1 5 m centres both ways

Dolerite Dyke in Blocks 18 *to* 23

3 30 The dolerite dyke in blocks 18 to 23 extends in a N 40° W—S40°E direction from a point five metres upstream of the axis to 84 metres downstream of the axis and had a dip of 50° in S 50°W direction. In blocks 22 and 23 the dyke had a width of 1 8 to 2.4 metres and its trend gradually changed from N40° W—S 40°E to N 25° W—S 25°E. It cuts across the dam foundation from the upstream end of block 18 to the downstream end of block 23. The width of this dyke zone at axis was 0.9 m to 1.2 m. which attained a width of 1.8 m. to 2.4 m. near the downstream toe of blocks 22 and 23.

This dyke zone was not detected during the exploratory stage. During excavation it was noticed as a weathered and weak strata and, therefore, the excavation was taken deeper than the adjacent granite foundation. Exploratory holes were drilled to determine the nature and extent of this zone The dyke itself was also crushed and weathered upto a distance of 37 metres downstream of the axis. From this point further downstream it was fairly fresh and compact, excepting along the hanging wall contact. Adjacent to the dyke, three large pockets of highly fractured granite-gneisses were located in blocks 20 and 22. In contrast to the hanging wall, the granite-gneisses occurring on the foot wall were quite massive and their contact with the dyke was well defined and tight From the extensive fracturing of the bed rock and the presence of a zone of crushed material with a thin seam of clay gouge on the hanging wall of the dyke, it was inferred that this contact might have been faulted, the clay gouge seam marking the approximate location of the fault plane The fact that the dolerite dyke was also crushed in certain reaches indicated that the faulting and the associated shearing had taken place subsequent to the intrusion of the dyke and that the movement had essentially

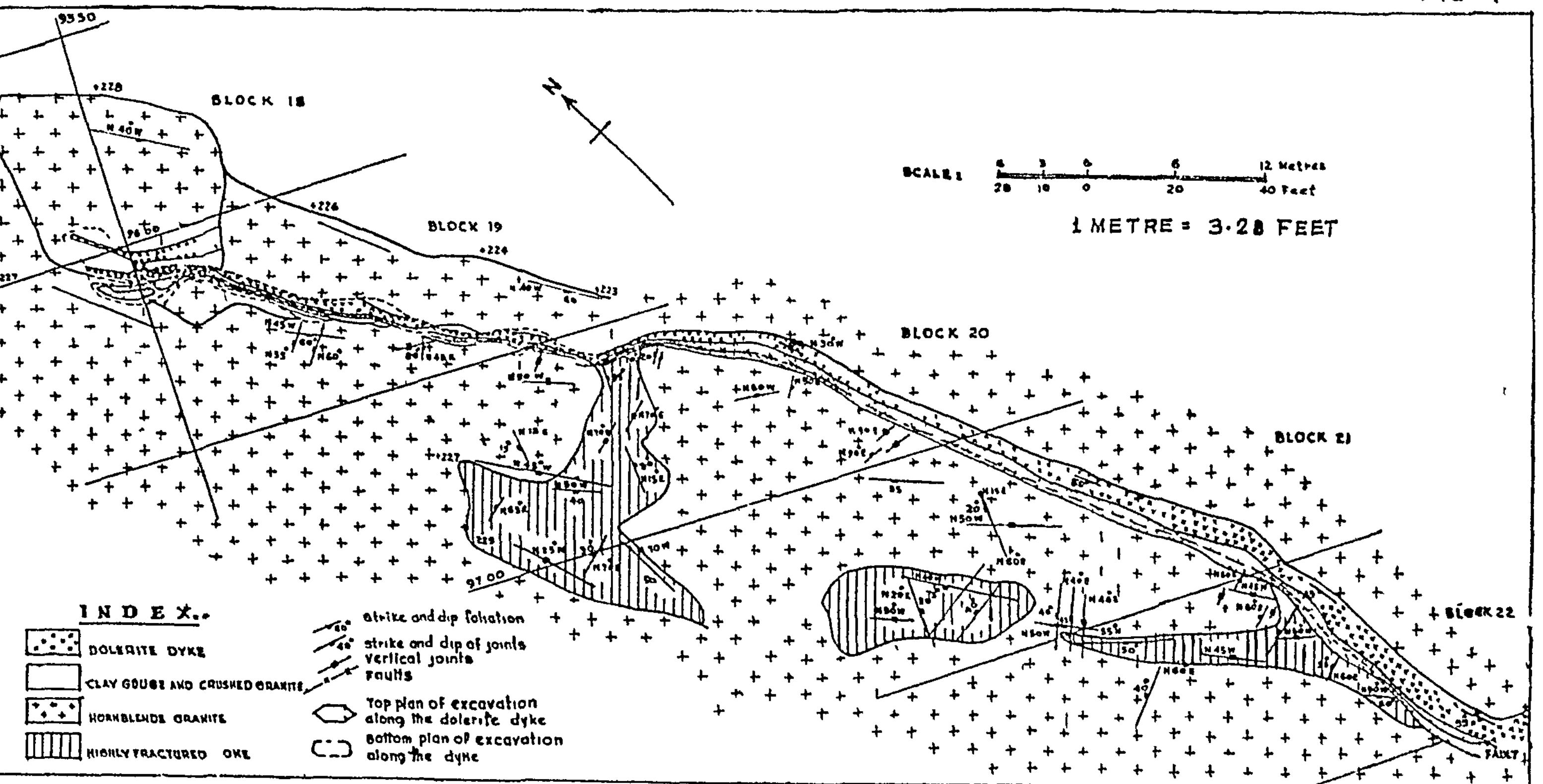
been confined to the weaker plane represented by the hanging wall contact between the dyke and the granite-gneisses. See Fig 4. The dyke was given the following treatment:

(i) Excavation was taken deeper along the fault zone. A vertical shaft nine metres deep was excavated with dimensions 15 × 12 metres at elevation 68.9 metres at the top and 8 × 3 metres at elevation 59.13 metres. The shaft was excavated to level 59.13 m. where good rock was struck. In the remaining length of the dyke zone, the dyke was excavated to a depth at least twice the width of the fault. The deepest excavation level in this length is 64 m. Radial grouting was done from the bottom of the shaft with holes nine m. deep and grouting was extended along the dyke zone with holes drilled from both sides of the dyke zone. It was found that the actual dyke zone proper was tight due to the existence of clay (thickness varying from 5 mm. to 75 mm. along the entire length of the dyke). But the rocks on either side of the dyke zone took an appreciable amount of grout. The total consumption of cement in the dyke zone was 1,522 bags (76.1 tonnes) with an average of 0 85 bags (45 kg.) per metre run.

(ii) The upstream shaft was concreted from the bottom of the shaft from 59 13 m. level up to the general foundation level of 70.1 m. with grout condulets provided at the contact planes of concrete and rock. At the top of the shaft a reinforced cement concrete raft was provided to span over the shaft portion with 30 kg. per metre rails at 0.6 metre spacing both ways This measure was expected to take care of any possible settlement in the soft zone by distribution of the load to the adjacent sound rock. For this purpose it was ensured that the raft rested firmly on the sound granite-gneisses on either side From the top of the reinforced cement concrete raft the masonry of the dam was started. In the remaining portions of the trench, concrete was filled in the narrow section at the bottom for about 0.9 metre height Over the concrete the masonry was started.

(iii) In the remaining reach of the soft zone, where the excavation had been carried down to a depth equivalent to twice the width of the weak zone and back filled with cement concrete, it was expected that the loads would be effectively transmitted by the cement concrete plug to the sound granite-gneisses forming the sides of the weak zone.

(iv) Stage grouting and grouting of the shrinkage joints of the cement concrete back fill were also made. Water pressure relief



PLAN SHOWING THE GEOLOGY AND THE EXCAVATED DETAILS IN THE DOLERITE DYKE AND THE ASSOCIATED FAULTED ROCK. BLOCK 18-23

pipes were also provided all along the soft zone at regular intervals, and these were connected to the galleries.

Crushed Zone in Block 55

3 31 In block 55, a crushed zone of about 0.6 m. to 1.2 m. width and having a dip of 45° towards the right abutment extended at right angles to the axis of the dam from the upstream to the downstream edge of excavation, traversing the full width of the dam foundation

This zone was detected during the wedging and barring of the foundation. The foundation in this block is of excellent fresh granites. But along the line of the crushed zone, a highly fractured rock was met with. When the excavation by wedging and barring was continued, the actual extent of the crushed zone was seen at foundation level. Diamond drill holes were put in order to determine the depth and direction of this zone. The drill hole data indicated that the crushed zone extends to a considerable depth at the same angle and direction. The following treatment was given

(i) A shaft of size 11.3 m. long and 5.2 m. wide was excavated at the upstream end of the zone to a depth of 9.1 m. below the general foundation level in the block, in order to act as a cut off. This trench was drilled and grouted from the bottom and sides at different levels with radial holes 9.1 m. deep and 25 m. diameter.

(ii) In the remaining length of the zone, excavation was taken to a depth equal to twice the width of the zone. The width of the crushed zone varied from 0.6 m. to 1.2. m. containing a clay band of 25 to 75 mm. thickness within the crushed zone section. The adjacent areas along the length of the trench in blocks 56 and 57 also were partly affected by this zone and were highly fractured, and they took a considerable amount of grout The total cement grout consumption in this area was 547 bags (27.5 tonnes of cement)

(iii) Grouting with 9 1 m deep holes was done all round the shaft in a radial pattern starting from the bottom of the shaft.

(iv) Grouting was extended for the full width of the foundations in the area adjacent to the crushed zone The crushed zone proper was very tight, but the area adjacent to this zone was highly fractured and sheared. These consumed an appreciable amount of grout. The total cement grout consumption in this reach was 547 bags (27 50 tonnes) with an average of 30.27 bags per running metre (1512 kg. per metre)

(v) The upstream cut-off shaft as well as the trench excavated along the crushed zone was filled up with 19 mm. gauge

aggregate concrete, upto the general foundation level and covered by a reinforced cement concrete raft to span over the crushed zone. The reinforcement consisted of 30 kg per metre rails with 0.6 m. spacing both ways. Over the reinforced cement concrete, masonry was laid

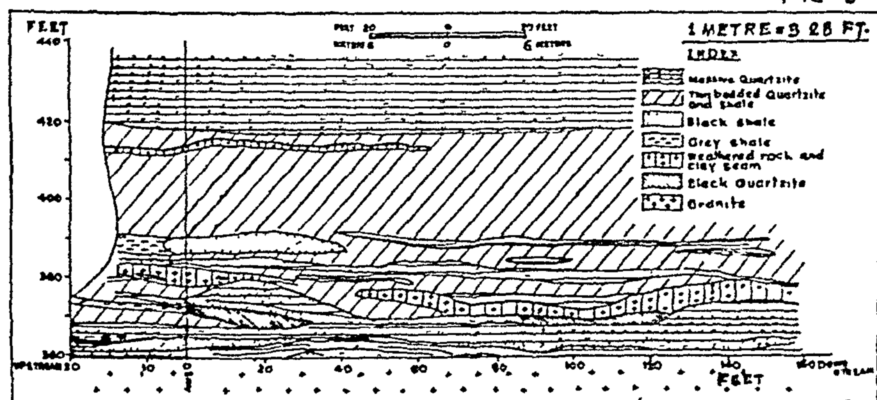
(vi) Grout condulets were embedded for grouting the contact planes of concrete and rock surface in the trench portions.

(vii) Uplift pipes were installed in this block along the crushed zone for observations at a later stage

Joints in Blocks 70 *A and* 71

3 32 The dam is founded on quartzite rock in these blocks Open joints were found in blocks 70 A and 71, 50 mm. to 75 mm. wide at the surface and narrowing down to 25 mm at lower levels In block 71 this joint was traversing the full width of the dam and extended to a considerable depth below up to the shaly strata. The open joint was treated as follows: (See Fig. 5) (i) An open trench 3 m. to 4 5 m. wide was excavated along this joint and a number of drill holes were put on either side of the joint

FIG-5



GEOLOGICAL SECTION OF THE VERTICAL FACE BETWEEN BLOCK NOS 70A & 71

The spacing and inclination of grout holes were proposed so as to intercept the joint at different depths (ii) The joint was thoroughly cleaned through all the holes and grouting was done to refusal and the trench was back filled with concrete, leaving grout condulets along the rock surface. (iii) A reinforced concrete raft was laid for the full length of the trench In addition, three rows of deep holes extended to the granite level, were drilled on the upstream side of the dam parallel to the axis for the full width of the block and grouted The joint in block 70 A was not extending to the full width and as such the length of the trench

excavated was smaller. but all the above precautionary measures were taken.

General Treatment of Flanks

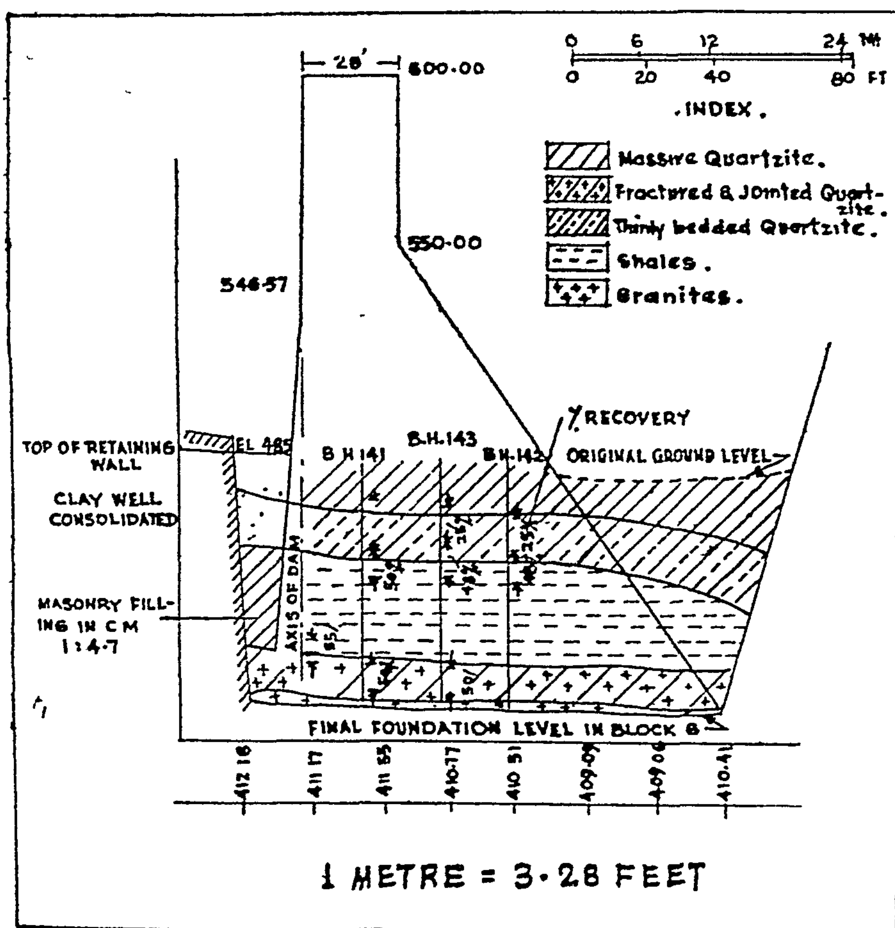
3 33 While the bed of the river consists of massive and fresh granite rocks, the flanks of Nagarjunasagar dam are of an unreliable formation, consisting of flat bedded sedimentary rocks made up of quartzites with shaly intercalations. The treatment of this strata of complexity required highly technical engineering and geological skill and expertise. In order to ensure that there shall be no undue settlement of the dam built on these formations, strengthening measures of the underlying strata were considered and discussed with the Board of Consultants. It was felt that sufficient strength exists in the sub-strata and it was considered desirable to prevent as far as possible penetration of the shaly portions by water under pressure from the reservoir. This required an impervious curtain to stop the flow from the reservoir. At the contraction joints between blocks 5 and 6 on left abutment and between blocks 69 and 70 on the right abutment, the following geological formations of the upper Cuddapah were traced :

Formations	Left abutment level in metres	Right abutment level in metres
(1)	(2)	(3)
Massive quartzites	153 to 144	144 to 128
Thin bedded quartzite	144 to 136	128 to 118
Shales	136 to 128	118 to 112
Quartzites with thin shales	128 to 125	112 to 110
Granite-gneisses	125 and below	110 and below

Thin layers of soft materials were seen both along the contacts of the shales and the quartzites and along their bedding planes These layers of soft material were adjudged to have been formed partly due to the *in situ* alternation of the shales and partly due to the deposition of clay by circulating waters. Although the layers of soft material did not extend continuously beneath the entire foundation, it was apprehended that by virtue of the high degree of fracturing and jointing of the Cuddapah

formation, these soft seams may have inter-connections and thus provide continuous paths of leakage after the impoundment of the reservoir. Further, despite the fact that the Cuddapah shales were mostly siliceous, some of them softened under prolonged saturation and as a consequence

FIG · 6



CROSS SECTION SHOWING THE GEOLOGICAL FORMATIONS IN BLOCK NOS. 5-6 AND TREATMENT IN THE UP-STREAM OF DAM.

showed considerably less bearing strength than in the dry state While the various tests conducted revealed that the shale, as a whole, possessed sufficient strength, the presence of layers of softer material and the susceptibility of the shales to softening and reduction in their bearing strength upon saturation had to be considered in evolving remedial treatment.

The first and foremost consideration was one of effectively preventing the leakage of water under pressure and the flowing of the fines from the foundation materials. Grouting tests carried out at the site indicated that the shales were not amenable to effective grouting. Electrical analogy tests in the laboratory showed that the provision of concrete cut-off trenches, although definitely advantageous, did not provide a complete solution. The Consultative Committee of the Nagarjunasagar project, after a thorough discussion of the problem, suggested that the shales should be protected from deterioration either by direct contact with the reservoir or indirectly through seepage and to ensure that no settlement of the dam took place.

Treatment of Left Flank

3 34 The following recommendations were approved by the Consultative Committee for the treatment of the left flank of the dam and they were carried out :—

(i) The gap between the face of the dam and the excavation slope in block 6 is to be filled up with masonry from the granite level of 125 m up to the top of slaty shale zone i e 140.21m. and the rest with clay, well consolidated up to ground level End retaining wall from level 140.21 m to 147.8 m is to be built near the junction of blocks 6 and 7 to retain the earth filling.

(ii) A grout cut-off is to be provided at the upstream heel of blocks 4 and 5 as well as along the alignment of the upstream wing wall with one line of grout holes at 3 m spacing, the grout holes extending 3 m. into the granites.

(iii) Four rows of radial curtain holes with radius of 7.5, 15, 22 50 and 30 m from the junction of blocks 4 and 5 are to be provided covering the area between the edge of excavation in block 6 and wing wall. These holes also should extend 5 m into the granites.

(iv) In the contact plane between masonry and vertical foundation face at the junction of blocks 5 and 6, the soft and disintegrated material is to be scooped out and backfilled with concrete as the masonry of the dam comes up. Grout condulets are to be provided for grouting the contact plane

Treatment of Right Flank

3 35 The following are the suggestions made by the Consultative Committee for the treatment of the right flank of the dam. A similar method of treatment has to be adopted for the right flank of the dam, in

blocks 69 to 79 as adopted for similar foundation strata as on left flank and these were carried out.

(i) The gap between the upstream face of the dam and excavation slope in block 70 is to be filled up with masonry from the granite level of 109.7 metres up to the top of slaty shale zone i.e up to level 121 9 m and the rest with clay The end retaining wall from 121 9 m. to 135.6 m level is to be built near the junction of blocks 69 and 70 to retain the earth filling

(ii) Grout cut-off is to be provided at the heel of the dam in block 70, the grout holes extending 3 metres into the granites

(iii) On the upstream of blocks 71 to 75, where the approach of the canal and penstocks is located, the rocks are to be treated for a distance of 15 m from the front face of the dam by consolidation grouting blanket, with holes 9 m. deep As an additional precaution, a length of 30 m on either flank on the upstream side of the affected area may be covered with masonry 0 9 m in thickness Further investigations may be done to see if additional length has also to be covered with masonry This masonry should be tied down to granite at foundation level so as to prevent seepage into the shaly strata behind.

3.36 The treatment of left and right flanks of Nagarjunasagar dam was carried out as per the above recommendations of the Board of Consultants. Masonry also was laid on the upstream of either flanks covering the quartzites and shales up to the junction and of the sedimentaries and the granites and extending for a length of 30 5 metres upstream of the dam.

Fig 7 and 8 show the plan of grouting on the upstream side of the contact zone of sedimentaries and on the left flank and a cross-section of the masonry blanket 15 metres upstream and parallel to the axis along blocks 4 to 7 The treatment given to the right flank is similar

RESUME

3.37 The foundation treatment of Nagarjunasagar dam was mostly carried out departmentally, except the operation for high pressure curtain grouting, which were awarded on contract to M/s Kilburn & Co , and M/s. Western Bengal Coal Fields, Calcutta

For consolidation grouting, the maximum depth of grouting was 9 metres and the method of injection of grout was by stage grout with rubber packers For pressure grouting, the depth of drilling was

FIG·7

ch 90+30
BLOCK 8
ch. 89+70
BLOCK 7
EL. 420
RIVER FLOW
ch 89+00
RETAINING WALL
BLOCK 6
MASONRY FILLING UPTO EL. 460 FT. & WELL CONSOLIDATED CLAY FILLING ABOVE EL. 460 FT.
ch. 88+35
BLOCK 5
ch 88+10
CURTAIN GROUTING
SCALE
0 24 Mt.
0 80 Ft
BLOCK 4
WING WALL
ch 87+40
165'

PLAN OF LEFT FLANK SHOWING PROPOSALS FOR GROUTING ON UPSTREAM SIDE OF CONTACT ZONE.

FIG· 8

570
550
530
510
490
470
450
430
DATUM 410
BLOCK 4
BLOCK 5
BLOCK 6
BLOCK 7
INDEX
Massive Quartzite
Thinly bedded Quartzite
Shale
Granite
SCALE 0 40 feet
ASSUMED GROUND LEVEL
EL 499
EL 473
existing deep cut filled with masonry lean mix

CROSS SECTION OF MASONRY BLANKET 15 M. UPSTREAM AND PARALLEL TO THE AXIS ALONG BLOCK 4 TO 7

45 metres. Garden Denver Grout pumps were used. These were operated pneumatically. Water cement ratio varied from one cement to ten water to one cement to two water by volume The average cost of grouting per linear metre was Rs 70 The cost of drilling per linear metre was Rs 66 for wagon drills and Rs 140 for diamond drills. The tables are specially given to indicate areas of intensive groutability.

Nagarjunasagar dam is founded on hard granite rocks in the gorge portion from block 6 to 69, whereas the flanks are founded on quartzites and shales from block 1 to 5 and 70 to 79. If the foundations of the flank blocks were to be taken on granites, it would have been highly expensive. The foremost consideration was one of effective prevention of the leakage of water under pressure and flowing of the fines from foundations. The problem has been effectively solved by protecting the shales from deterioration either by direct contact with the reservoir or indirectly through seepage. In order to ensure that no settlement of the dam took place, effective grouting was carried out and the shales were cut-off from the reservoir by masonry blanketing. Perfect vigilance is necessary to see that there is no seepage from the flank blocks, leading to flowing of the fines, and in case there is any, it should be promptly arrested by grouting through the grout galleries.

CHAPTER IV

PROJECT MANAGEMENT

General

The management of a project consists mainly in proper planning, organisation and administration, and efficient monitoring Successful, economic and timely completion would finally depend upon the smooth progress of the entire project in all its aspects from the beginning to the end Based upon this, will depend the economic and efficient execution of the project for the realization of early benefits. The administrative tasks cover long-term planning, build-up of organisation, laying down of policies and procedures, financial control, preparation of a realistic schedule of rates, matching the construction programme with the development of irrigation, power, agro-economics and general developments in other auxiliary matters.

Take off Arrangements

4 2 The first feasibility report of the dam for irrigation was given by the Irrigation Department of former Hyderabad State in 1950 With the finalisation of the joint report by Andhra and Hyderabad States in March 1954, steps were taken by both the States for the preliminary works required for the take-off of the project. Approach roads to the dam site were started and detailed investigations for planning the construction of the canal were taken up.

The erstwhile Hyderabad State gave administrative approval to the preliminary works of the project on June 17, 1955. The works connected with the dam and the left canal were taken up by Hyderabad State and that of the right canal by Andhra State. Thus regular investigations for Nagarjunasagar dam were started early in 1954 under the administrative control of the State Irrigation Department of the former Hyderabad State, under the Chief Engineer, Mr. D. V. Rao. The dam organisation took birth with an investigation division of the Irrigation Circle of which the author was the first Executive Engineer. This circle was under the administrative control of the Superintending Engineer, Mr M. Jafer Ali, who later on became the first Chief Engineer of the dam organisation.

The investigation division, in addition to conducting the preliminary and regular surveys of the dam and the left canal, had also to build the approach road to the dam site which took off from the Devarkonda-Miryalaguda road from the village of Peddavura. The approach road

is 20 km long and was completed in a record time of four months by the end of 1955.

Similarly from the right flank of the dam, an approach road was sponsored by the Government of Andhra State from Macherla to the dam site, a distance of 23 km It was completed by 1955.

The Control Board

4 3 The project work commenced as a joint scheme of the former Andhra and Hyderabad States To ensure efficient and economic execution of the project, the Government of India set up the Nagarjunasagar Control Board on June 16, 1955 An Administrator for the entire project, Mr. S. Chakravarti, and three Chief Engineers were appointed : one for the dam, Mr M Jafer Ali, the second for the right canal, Mr G. A. Narasimha Rao, and the third for the left canal, Mr. T. S. Murthi The accounting organisation was headed by Mr. A L. Saxena who took over charge as Financial Adviser and Chief Accounts Officer

4 4 The Nagarjunasagar project comprised of three major components (i) the storage reservoir, (ii) the canal system and (iii) power development. The dam was designed for irrigation and power development and was under one Chief Engineer. To start with, there were two Chief Engineers for the canals, one for the left canal and the other for the right Later on, there was only one Chief Engineer for both the canals. All the Chief Engineers were under a single Administration. Each Chief Engineer had an independent organisation The programmes of the Chief Engineer Dam, the Chief Engineer left Canal and the Chief Engineer Right Canal, had been co-ordinated so that the canal system was ready to receive water by the time the dam rose high enough to feed sufficient water into the canals for irrigation The power portion of the dam and the connected works were taken up by the Chief Engineer Dam, in consultation with the Chief Engineer of the State Electricity Department.

Finance

4.5 The entire cost of the project was advanced by the Central Government to the States on a loan basis to be repaid in instalments. The Board was in over-all charge of the project and as originally constituted consisted of the representatives of the two participating States and the Central Government In consultation with the participating States, the Central Government appointed an Administrator to co-ordinate the engineering and developmental aspects of the project and to ensure among other things, expeditious land acquisition, localization of the layout and rehabilitation of displaced persons so that there would be no time lag between the completion of the dam and the utilisation of benefits The Board was

assisted by a whole-time Secretary and a Financial Adviser-cum-Chief Accounts Officer.

Delegation of Powers

4 6 The Board was not a statutory authority, but an administrative set-up with no inherent administrative or financial powers. The decisions it took were, therefore, recommendatory. Therefore, the basic problem was how to establish the autonomy of the Board and thus maintain flexibility and initiative so essential for the speedy execution of the project. To meet these needs, the Governments of Andhra and Hyderabad delegated to the Board powers to enter into contracts, sanction expenditure and take other decisions involving financial commitments in respect of the common works. The two State Governments also decided that the orders of the Board should be accepted in Audit as having the sanction of the Government concerned. These orders, in effect, vested the board with the powers of a State Government.

4.7 With the vesting of such powers, it became necessary in practice for the Board itself to delegate some of its own powers to the Administrator the Financial Adviser and Chief Accounts Officer, the Secretary and the Chief Engineers Accordingly, at the fourth meeting of the Board held on February 22, 1956, powers were delegated to the Administrator to make postings to vacant posts of officers of and below the rank of Executive Engineers, to transfer officers from one post to another, to grant leave and generally to exercise all such powers as had been specified in the delegations for the purpose of day-to-day administration. Some of these powers, in addition to powers of a technical nature, were exercised by the Chief Engineers also. All these delegations were ratified by the State Governments.

4.8 The powers of the Chief Engineers are normally derived from the P. W. D. codes drawn up decades ago, to suit conditions then prevailing These powers are restricted in respect of administrative matters, thus hampering both adequate control and day-to-day administration. Therefore, the delegation of powers to the Chief Engineers of Nagarjunasagar dam and the canals was accordingly rationalised so as to bring the powers more in line with the present system of execution of works and accounts. The result has been that the delegation gave much larger administrative powers and broad-based the financial powers and thereby ensured that. in respect of important matters, the Chief Engineers took decisions in consultation with the Financial Adviser or Administrator as and when necessary.

4 9 As the Board met only once in six to eight weeks, it became necessary to prescribe an emergency procedure to provide for expeditious disposal

of emergent works. This subject was considered at the seventh meeting of the Board held on June 27, 1956 and it was decided that the agency for the purpose should consist of the Chief Minister, the Administrator and Financial Adviser

Reconstitution of Control Board

4 10 Later on, Hyderabad State was reorganised. Telegana was integrated with Andhra which became Andhra Pradesh. Subsequent to the formation of integrated Andhra Pradesh on November 1, 1956, the Board was reconstituted by the Government of India on that date. The Board, as reconstituted, consisted of the following members

Chief Minister of Andhra Pradesh : Chairman

Ministers of Finance and Irrigation, Andhra Pradesh.

Secretary, Ministry of Irrigation and Power, Government of India or a member nominated by him

Joint Secretary, Ministry of Finance, Government of India, or a member nominated by him

Chairman, Central Water and Power Commission, or a member nominated by him.

Administrator, Nagarjunasagar Project

Chief Engineer, Nagarjunasagar Dam and

Chief Engineer, Nagarjunasagar right and left canals.

The left and right canals were brought under a single Chief Engineer as the work-load did not warrant a separate Chief Engineer for each canal Later on from 1960 onwards, the work-load increased with a network of the canal systems on the left and the right. The work became unmanageable for a single Chief Engineer. Yet the Government considered having only a single Chief Engineer as a matter of economy. This was not in the larger interest of efficient and early completion of the canal system

Approval for Emergent Works

4 11 The procedure for emergent works was reviewed by the Board at its tenth and eleventh meetings when it was agreed that it would be sufficient for the Administrator and the Financial Adviser to prepare a joint note and take the orders of the Chief Minister, Andhra Pradesh In important matters, however, presenting special features or those which were of unusual complexity, for example, purchase of machinery, when it was considered necessary to consult Central Government representatives on the Board, the note was required to be sent to the Secretary, Govern-

ment of India, Ministry of Irrigation and Power, leaving it open to him to consult the Ministry of Finance or the Central Water and Power Commission or the Director General of Supplies and Disposals, as the case might be All final orders issued were required to be placed before the next meeting of the Board for confirmation.

Review of Progress and Monitoring

4.12 Till the end of March 1957 the Board met ten times, approximately at intervals of eight weeks. Practically, every one of the functions specified in the resolution constituting the Board was brought under focus, that is, over-all control, scrutiny of estimates, preparation of designs, delegation of powers, preparation of schedules of rates, rules of business including emergency procedure, review of progress, the programme of construction, development and utilisation of water, rehabilitation policy, etc The following standing items figured on the agenda of the Board at every meeting, enabling it to have a continuous picture of the progress, programme and the problems relevant thereto :

Review of action taken on the minutes of the previous meetings
Review of the progress of work.
Review of the future programme of work.
Forward planning of men, machinery and equipment.
Measures for economy
Budget and accounts
Development.

In addition, special problems such as labour amenities, the purchase procedure, the recruitment of specialists, sanction of project estimates, public participation etc., were considered from time to time.

4.13 Vested with the powers of a State Government and thereby divorced from the background of the rules, regulations and procedures inseparable from ordinary departmental administration, the working of the Board in effect became autonomous For co-ordinating and processing the business of the Board, a number of standing committees were set up The sub-committees were a necessary adjunct to the working of the Board in charge of a project of this magnitude. Accordingly, the following standing committees were set up :

Project Working Committee.
Sub-committee on Excavations of Nagarjunakonda.
Development Committee and Agro-economic Survey Technical Advisory Committee.

In addition, the following special committees were constituted for consideration of specific problems :

(i) Personnel Committee
(ii) Committee on Accounting and Financial Procedures
(iii) Stress Committee of Engineers.
(iv) Rates Committee

Project Working Committee

4.14 The Project Working Committee consisting of the Administrator, the Financial Adviser, Special Chief Engineer (Irrigation), Andhra Pradesh and the Chief Engineer for the dam and the canals, generally met twice a month and were charged with the duty of ensuring close liaison in the working and co-ordination in the activities of the Chief Engineers for the dam and canals, bringing up common problems for discussion, reviewing progress, taking all possible steps for speeding up the work and finally considering measures for economy from time to time

Sub-Committee on excavation of Nagarjunakonda

4.15 The function of the committee on Nagarjunakonda excavations, which met once a month, was to review the progress of excavations of archaeological monuments from month to month and suggest ways and means of resolving difficulties to ensure that the targets for the completion of the excavations and the reconstruction of the monuments were strictly adhered to

Development committee

4 16 On May 9, 1956, the Board decided to set up a development committee to consider the following aspects .

(*a*) To consider and advise on all problems relating to development, to match the development of irrigation with the development of the ayacut and in particular the determination, localisation and development of the ayacut, the nature of irrigation to be undertaken and crops to be grown, measures of assistance to the ryots, provision of roads, soil conservation and afforestation, and

(*b*) to suggest principles and methods of rehabilitation with particular reference to the basis of rehabilitation and places for resettlement and fix the responsibilities of the Government concerned for rehabilitation, to suggest a phased programme of land acquisition from time to time and to ensure close liaison between the project authorities and the acquisition staff in all matters relating to land acquisition, particularly the need for using the emergency provisions of the Act, pace of acquisition, payment of compensation, etc,

Agro-economic survey

4.17 The Board also constituted a technical committee for the purpose of designing in some detail, the agro-economic survey recommended by the Development Committee and reviewing and guiding its operations from time to time.

Planning

4.18 Careful planning is a significant feature of the project right from the beginning. Planning starts right from the financial sanctions from the Government upto the engineers' level for expenditure. This has to synchronise various activities, men, materials, equipment and accomplishment of events to achieve the targets as programmed. Planning includes the phasing of the programme of construction, requirements both immediate and forward as to personnel, scarce materials like cement and steel and machinery, sound organisation, adequate accounting arrangements and financial control, arrangements for roads, camp buildings, water, electricity and other services, labour amenities, research laboratories, continuous attention to economy, etc. Everyone of these aspects was brought under careful review from time to time. Decisions which might result in maximum economy had to be taken in the pre-construction stage, and depending upon the adequacy of investigations suitable design and estimates based on an up-to-date analysis of the rates and costs drawn up in actual practice.

As a first step, the investigations already made and the data already collected were reviewed preliminary to the drawing up of the general plan. Where data were not available, steps were immediately taken to collect them, for example, investigations by geologists, drilling, railway surveys, etc. Having regard to the fact that the design of the dam had not been settled in the earlier stages, the programme at that stage naturally contemplated only the taking up of works which would have to be done in any case, whatever the shape of the future general plan, that is, bridge across the river, approach roads, camp buildings, service roads, water supply and electric installations, core-drilling in the river bed, trial excavations of foundations, collection of sand on a trial basis etc. Indeed the officers were actually conscious, all the time, of the need to put off works in respect of which there was a doubt as to their place in the general plan. It was against this background that construction activities proceeded. Right from the second meeting of the Board on October 29, 1955, the future programme of work was a standing item on the agenda. This was to ensure that continuous attention was given to the overall need that all sanctioned works would fit into the general plan and that no action was taken in the early stages which might lead to delay or unnecessary or wasteful expenditure. The Chief Engineer held meetings with the engineers for drawing up programmes before starting important works.

The programme and progress were controlled by preparing bar charts in advance. Engineers had to give explanations for any shortfall in progress, and the resources of the project were mobilised to keep to the programme and targets.

Organisation

4 19 The organisation for the dam construction, which started in 1954 with one Executive Engineer, gradually developed by 1957 into three circles headed by three Superintending Engineers and 17 Executive Engineers with the necessary Assistant Engineers, Supervisors and clerical staff. There was a separate organisational set-up for the construction of canals of the project.

Broadly the organisation that was built up for various sections of the dam could be divided into the following sections :

> Technical, Accounts, Stores, Workshop, Medical and Public Health, Labour and Labour welfare, Land Acquisition and Rehabilitation, Education, Law and Order and Vigilance. The above sections are described below in detail:

Technical Section

4 20 While the State Government has, by and large, met the staff requirements of the project, the deputation of experienced personnel in some cases, which was inevitable in the circumstances, created some difficulties, lack of general experience and particularly specialist experience, as it became almost impossible to attract specialists through the ordinary procedure of deputation. Therefore, the Board created a cadre of Specialists for the Executive Engineers with a higher scale Three specialists were required, one for drilling and grouting, the second for designs and the third for tests and laboratories Accordingly, three specialist Executive Engineers were appointed, Mr. R C. Rao for drilling and grouting, Mr. P. V. Rao for designs and Mr S Balasubramanyam for laboratories and quality control

4 21 The organisation was programmed depending upon the type and extent of the workload In the early period, the preliminary work on the dam comprised of . the construction of approach roads, railway lines, camps and buildings, water supply and drainage, electrification and construction power, investigation of quarries for materials, such as stone, earth, sand, and surkhi, exploratory drilling operations, the telephone system and preparation of preliminary specification drawings

4 22 The construction of approach roads was entrusted to the Investigation Division Separate divisions were formed for the camps and

buildings, electrification and construction power, quarries and materials and exploratory drilling operations. Water supply and drainage was attached to the Building Division and the telephone system was with the Electrical Division. Preparation of preliminary specification drawings was entrusted to the Central Water and Power Commission, Government of India, Detailed drawings and lift sheets were prepared in the designs wing of the Chief Engineer's Office at the dam site under the specialist Executive Engineer.

4 23 Before starting the construction work, coffer dams were taken up and detailed surveys of the dam were conducted for the spillway and appurtenant works. An important work was the diversion of the river, excavation of the foundations, erection of batching and mixing plants, and the collection of materials like stone, sand and surkhi.

4 24 For the dam construction, two divisions operated, one from the left bank and the other from the right. The left bank division started the main coffer dam on the left of the river and stripping of the left flank. The right bank division started stripping of the right flank. All the above works were started in full swing right from 1956, under the able guidance of Mr. M. Jafer Ali, Chief Engineer.

4.25 The quality control organisation was established right from the inception of the dam construction. It was headed by a Superintending Engineer with complementary staff, directly under the Chief Engineer. Mr. K. V Sreenivasa Rao was the first superintending Engineer. He formed the circle for quality control The circle was named Inspection and Control Circle The first Superintending Engineer for the construction Circle was Mr. A. R. Chellani, whose services were obtained as a specialist for construction from the Hirakud project, which was practically completed by that time. Mr P. T. Malla Reddy assumed charge as the first Superintending Engineer for buildings and roads. The inspection and control organisation ensured the desired quality of construction right from the procurement of materials from various quarries to their point of placement. As a high masonry dam of 124.7 m (409 feet) height was to be constructed for the first time in the world, immense emphasis was laid on the quality of construction in order to achieve the desired results, which would have a great bearing on the future masonry high dams to be built subsequently in the country and abroad.

4 26 As a part of the technical staff, workcharged staff were specifically appointed in the organisation to supervise departmental works to be executed according to standard specifications. They were to supervise the works given on contract and also carried out departmentally. The workcharged staff employed to supervise the works were called maistries, work inspectors etc. The mechanical workcharged staff to run the

machines were designated as foremen, mechanics, electricians, helpers etc. The workcharged staff were not eligible for pension like the provincial staff of the Government. Yet they enjoyed the benefits of gratuity, provident fund and limited leave rules. They were appointed for a particular project and their services were not carried forward from project to project At the close of the project they were retrenched, being given the terminal benefits of their services Most of them were reappointed in other projects in view of the precious experience gained by them.

Accounts Section

4 27 Apart from technical personnel, the shortage of experienced accounts personnel proved a severe handicap As the State Government did not find it possible to meet the project requirements, it became necessary to recruit them from the Accountant-General's Office on deputation. As the response from this, however, was poor, arrangements were made to recruit them by advertisement and give them intensive training for six months

A perfect accounting system is an essential requirement of any public undertaking. The organisation for accounts was headed by a Financial Adviser-cum-Chief Accounts Officer. The set-up was in charge of compilation of project accounts, and payment of project bills after pre-check. The project accounts were made available for concurrent audit to the Accountant-General whose deputy was stationed at the dam site. Thus, the engineers were relieved of the duties of issue of cheques, preparation of consolidated monthly accounts and submitting them to the Accountant General. These were primarily responsible for the correct maintenance of the initial accounts This enabled them to concentrate on the execution of works A novel feature of the accounting system at Nagarjunasagar was that all book adjustments were eliminated Payments were made and received by cheques and bank drafts The project accounting system is described in full in Chapter XI

Stores Section

4 28 To ensure prompt and regular procurement and flow of materials required by the various units of the project, a separate stores section, headed by an Executive Engineer, was formed Mr D. Seetarama Rao assumed charge as the first Executive Engineer in charge of stores In this division, in the advanced stage of construction, about 30,000 items of materials were procured and handled The division was managed by a Mechanical Engineer assisted by an Accounts Officer, three Assistant Engineers and clerical staff The division handled about Rs 22 00 crores worth of materials A new stores accounting system with bincards was evolved for effectively coping with huge transactions.

Work Shops

4.29 Apart from the various field workshops for dam and electrical divisions, a central workshop was established. Mr. E. Floate was the first Executive Engineer. He formed the main workshop which comprised the Machine shop, the Structural section and the Foundry section.

In addition to normal repairs to machinery, the following important works were carried out in the workshop .

Trestle bridge, Cement silos, Gates for construction sluices, launches, Shuttering plates for concreting and Bearings for spillway bridge.

With increase in activities, separate auxiliary workshops had to be opened, for transport and heavy machinery. With the completion of the dam these two workshops were closed. The main workshop continued for the maintenance works of the dam and the canals and for local industries.

Medical and Public Health

4.30 About 45,000 persons were at work at the peak of construction. There was a population of 70,000 in the two townships of Vijayapuri North and Vijayapuri South on either flank of Nagarjunasagar dam. The hospital named Kamala Nehru Hospital was headed by a Civil Surgeon (Chief Medical Officer) with ten doctors of the cadre of Assistant Medical Officers with the necessary staff. Dr. P. Rami Reddy was the first Civil Surgeon. He established a temporary hospital at the dam site and planned the bigger hospital, the Kamala Nehru Hospital. Among the ten Assistant Medical Officers, two were Lady Doctors. The hospital had 110 beds and was fully equipped just like a district hospital. Besides, a 20-bed children's ward was added. It was built from public donations in 1967. Dispensaries were opened on the Right bank at the Pylon and the Bandala Karva quarry camps.

4.31 The staff required for the medical and public health sections was drawn from the Andhra Pradesh Medical and Public Health Services. They were under the administrative control of the Chief Engineer of the dam From 1968 when the work on the dam decreased, 50 per cent of the medical and public health expenses were debited to the State Government. In the previous years, the full expenditure was borne by the dam organisation.

4.32 The Public Health unit was managed by an Assistant Director of Public Health, assisted by a Health Officer and necessary sanitary inspectors. Epidemics like cholera, smallpox and malaria were effectively controlled. The Public Health unit was independent of the Medical

section. With the completion of dam works, the separate public health section was closed and the medical officer looked after both the units.

Labour Welfare

4.33 A Labour Officer was exclusively appointed for looking after labour welfare

Land Acquisition and Rehabilitation

4.34 The area of submergence of Nagarjunasagar dam at full reservoir level is 285 sq km (110 Sq miles) Fifty-two villages and hamlets completely and five partially came under submergence. The population displaced was 24,204, consisting of 4,824 families. A Special Collector was drafted from the Revenue Department to organise acquisition of lands going under submergence and to rehabilitate the displaced families. The Special Collector also was in charge of the acquisition of lands for the canals. He was assisted by a number of Deputy Collectors with necessary staff. The first Special Collector was Mr. Durgaiah

For civil works such as the construction of wells, roads, etc., in the rehabilitation centres, the Special Collector was assisted by an Executive Engineer with three Sub-Divisional Officers. The displaced persons were rehabilitated in 24 centres.

Education

4.35 To cater to the educational needs of the children of the staff, contractors, labour etc , two high schools were established, in the Right Bank Colony and in the Hill Colony Six elementary schools also functioned at various places The staff required for the schools was mostly drawn from the State Education Department At the peak period of construction, the maximum number of children admitted in these schools was 4,500. Towards the end of the completion of the project, the schools continued but with reduced strength and were handed over to the Education Department of the State. Later, the school on the left bank was upgraded to a college.

Vigilance, Law and Order

4.36 The need for proper vigilance in a project of this magnitude is obvious A vigilance organisation had accordingly been set up under the Superintending Engineer, Inspection and Control. Three motor-cycle squads for inspecting stores in transit was created to ensure that stores were not tampered with during transit Three Vigilance Inspectors were appointed for this purpose These had jurisdiction over the project area, the store yard at Hyderabad and along the road leading to the dam

site from Hyderabad. The organisation was found to be useful, as, apart from routine checks, it had to detect theft of Government articles and also illicit use of stores.

4.37 The Vigilance Inspectors were in the grade of Circle Inspectors of the Police Department whose services were borrowed from the State. The Vigilance Inspectors used to be in plain clothes These inspectors also kept watch over un-social activities in the township. They were in direct touch with the Chief Engineer.

4 38 For law and order, a Deputy Superintendent of Police, assisted by a Circle Inspector and two Sub-Inspectors, with necessary staff, were stationed at the dam site. This section was completely controlled by the State Government under the directions of the Superintendent of Police of Nalgonda district. There were two police station houses, one in Vijayapuri North and the other at Vijayapuri South. There were police outposts at Hill Colony, the Bandala Karva quarry camp and the Nagarajunakonda quarry camp. The police station in Vijayapuri North served as the headquarters and was equipped with a wireless.

Progress of Work at Various Stages

4 39 A programme for construction of the dam project was drawn up to complete the work in nine years. Accordingly, a master bar chart was prepared therein marking various important items with schedules of quantities Against each item a time schedule was indicated marking the month by which the work would start and the month by which it would be completed. On the same bar chart, the monthly progress achieved with quantities was marked in a separate colour and close monitoring was done for programmes drawn up vis-a-vis the actual progress achieved. Similarly, for important individual works, subsidiary bar charts were prepared by the divisions. The modern practice of monitoring events and activities by Pert Charts and drawing critical paths was not adopted during the period.

The construction work started in 1956 and it was practically completed by 1968 except the crest gates, which were not cleared by the Government of India due to inter-state controversy over the apportionment of the waters of the Krishna river. In spite of building up a tremendous organisation for recording colossal achievements, the construction programme was delayed by three years, taking 12 years as against the nine previously programmed. The delay was mostly due to non-availability of funds due to which annual progress could not match with the programme.

With the starting of the construction work in 1956, preliminary works such as roads, buildings, construction power, water supply and

drainage arrangements constituting the pre-construction arrangements took two years. Along with these, the stripping of the foundation of the dam on the flanks, coffer dams and drilling operations were taken up. By 1960 the batching plants were fully erected and the masonry work was in full swing

4.40 By March 1961, the foundations of the dam were excavated and preliminary arrangements for various works such as camps, buildings, roads, railway lines and airstrip were completed. The infrastructure was ready and the scene of peak construction shifted to the construction of the dam, drilling and grouting, R C. C. works of galleries and raising of left and right earth dams

At the end of 1961, the progress of work was as follows

Drilling of foundations	90 00%
Grouting of foundations	95.17%
Masonry of the dam	31 97%
Concrete for the dam	40 37%
R C C for galleries	70.57%
Earth dams	30 09%

At the end of 1967, the progress recorded was as follows .

Masonry and concrete	89.51%
Left earth dam	93.8%
Right earth dam	77.2%

4.41 By 1966, the activities were increased and the staff was expanded to four circles headed by four Superintending Engineers and 21 Executive Engineers with the necessary technical and clerical staff With the tempo of progress getting gradually reduced, by 1968, there were only two Circles and six Divisions with necessary staff

4.42 In August 1967, the dam rose sufficiently high and water was let out into Nagarjunasagar canals with an irrigation potential of 2.63 Lakh hectares (6 5 lakh acres)

4.43 By 1968, the construction of the dam was practically completed and the Secretary to the Public Works Department, Mr. B. C Gangopadhyay, took over the functions of the Administrator of the Nagarjunasagar project, as the work load was reduced to a great extent. The last Administrator was Mr G. A Narasimha Rao, who was later designated as an Additional Secretary Ultimately in 1972, one single Chief Engineer, Mr. T. C Krishna Rao, took charge of Nagarjunasagar dam and left and right canals. He served the project for one year and was followed by Mr. D. Bala Krishna Rao.

RESUME

4.44 For the efficient management of the Project, in spite of the formation of the Control Board headed by the Chief Minister of the State as the Chairman, the Board did not prove a good construction agency for prompt execution of the project and for keeping up the targets of construction. It suffered from the same official restrictions and accounting procedures and financial sanctions and rules of recruitment for the staff, framed for normal activities of a government department. The progress of work suffered on several occasions for want of prompt financial decisions, secretariat approvals and inadequate funds. When once a project is started, targets should be kept up at any cost. With this background, the management of a project should not be entrusted to a government agency. It should be an autonomous body independent of government rules, financial breaks and outdated accounting procedures. Unless adequate powers are vested in the executive and timely and adequate finances provided, projects miss the schedules of time and cost.

CHAPTER V

PLANT LAYOUT AND COMMUNICATIONS

Considerable ingenuity had to come into play in the plant layout and in adopting the techniques of construction in the execution of the Nagarjunasagar dam, the largest masonry structure of its kind in the world. Keeping in view the materials locally available, the skilled and unskilled labour potential, the machinery available, the schedule of construction and allotment of funds, planning had to be done for the plant layout. The first consideration for planning was the decision taken to build this gigantic structure in masonry in preference to concrete. Accordingly, the layout for the plant and arrangements for the conveyance had to be made for various construction materials, requiring to be delivered at various sites Suitable machinery had to be selected and the plant layout devised at the lowest cost for the early completion of the project.

Various Materials Handled

5.2 The Nagarjunasagar dam is more than one and a half times in volume of the Hoover dam across the Colorado river in the U S.A. and when compared with Bhakra, it is one and a half times bigger and stores 27 per cent more water. The quantum of masonry, earthwork and other materials involved in the construction is equivalent to a 7 7 cm. thick cement concrete road 3.05 metres wide encircling the world. The dam comprises a 1349 metres long and 123 metres high masonry structure flanked by an earth dam of 26 metres height on either side. The total length of masonry and the earth dam is 4.8 km 5.66 m cu m of masonry and concrete and 2 3 m.cu m. earth work were involved in constructing this high dam The materials required for the construction are tabulated below :

Material	*Quantity*	*Source*	*Lead*
(*a*) Cement	1 2 m tonnes	Macharla Cement Factory	24 km
(*b*) Stone (Granite) .	5 92 m cu m	Quarries around the dam	3.2 to 12 8 km
(*c*) Sand .	2 44 m cu m	do.	11 to 35 km
(*d*) Surkhi ..	0 20 m tonnes	do.	2 4 to 16 km.
(*e*) Steel ..	60,000 tonnes	Steel Factories in India	1600 km

Road and Rail Links

5.3 The first step for the construction planning was to connect the project site by road and rail. There were two road approaches; one from Peddavura village situated on the Devarkonda-Miryalguda road, 19.2 km. north of the dam site and the second from Macherla town, 24 km. south of the dam site, which was also connected with the rail link. Peddavura is connected by a road to Hyderabad which is at a distance of 125 km. By building an approach road 19.2 km. long, the dam site was connected to Hyderabad, the capital of Andhra Pradesh. Hyderabad is a broad gauge railway terminus. A railway line was laid by the project from Macherla to the dam site for the conveyance of materials. About a kilometre below the dam site, a pre-stressed concrete bridge was built across the Krishna. This bridge connected Peddavura and Macherla via. the townships of Vijayapuri North and Vijayapuri South which were built for the workers of the project. Between the bridge and the dam site, roads were built along either flank of the Krishna.

Comparative Study of Various Methods of Construction

5.4 Masonry having been selected for the construction of the dam, the need for costly machinery was reduced to the minimum, simultaneously increasing the potential for employment of manual labour. Out of the 111 metres (height of the dam above the bed level), half the volume of the work was involved up to a height of 35 metres above the bed level of 75 metres. This lift for materials could be easily achieved by manual labour. Therefore, construction of the dam was planned in two stages. Mostly, the first stage involved manual lifting and the second stage mechanical lifting

The first stage was planned with timber scaffoldings which were utilised for trekking up for manual lifting and the second stage was planned by mechanical lifting with cranes. For work in the second stage, several techniques were considered for raising the dam, such as cable ways, cranes mounted on elevated steel trestles, belt conveyors and fixed tower cranes. These alternatives were studied analysing them for economy, speed, foreign exchange requirements, availability of steel and facility of operation To put high elevated steel trestles, steel was required Steel was costly and in short supply, and so this proposal was rejected. A span of 1447.6 metres was considered too long for the operation of cable ways; besides, this required foreign exchange With belt conveyors, it would not be easy to transport big stones up to one cu.m. size. Therefore, fixed tower cranes to lift materials were proposed as they required only a small quantity of steel.

Carriage by Lorries

5 5 Lorries were used for conveyance of construction materials such as stone, sand and surkhi The factors that weighed in favour of using lorries are summed up below ·

No foreign exchange was involved. The undulating topography of the country was made manoeuvrable by lorry transport. The quarries being dispersed over a large area, several trucks could be deployed, advantageously. Economy in capital cost was effected. Operation and maintenance was easy as mechanics and drivers were well versed with repairs and operation of lorries which were used in good numbers Quick construction and increased progress could be planned by distributing the stones to various blocks at different platforms In the event of failure of some trucks, the work was unaffected as there were nearly more than one hundred trucks operating only on rubble supplies, round the clock.

First Stage Construction

5 6 The first stage of the construction was planned with manual lifting of materials by means of scaffoldings and conveyance of materials by lorries, metre gauge railway and light railway of two feet gauge (0 61 m)

Period of Working

5.7 Allowing for rainy days, Sundays and holidays, 275 days were available in the year for construction. Masonry was proposed to be built only during day-time in an eight-hour shift, with a lunch break of one hour in the afternoon from 12 noon to 1 p m The working hours were 8 a m. to 1 p m and 2 p m. to 5 p m Rubble was lifted during day working hours and also in nights merely to be stockpiled on the blocks Concreting for copper sealing strips, galleries, spillway bucket, etc, was done during nights.

Programme and Out-turn of Work

5 8 The entire dam construction was planned to be completed in nine years and six months In the first two years, communications and buildings were built. The main coffer dam was completed. The foundations of the flanks of the dam were stripped Consolidation grouting of the foundations was started. With the completion of the communications, plant layout was taken up. With 275 working days in a year, the daily out-turn for various materials to be fed to the dam was worked out as follows :—

Rubble	.	1,10,000 cft.	(3115 cu m)
Sand	.	55,000 cft	(1558 cu.m)

Cement	..	450 tons	(457.2 tonnes)
Surkhi	..	100 tons	(101 6 tonnes)
Mortar	..	55,000 cft.	(1558 cu.m)
Aggregates	..	16,000 cft.	(460 cu.m)

5 9 The planning, procurement and supply of enormous quantities of these materials is detailed below .

Rubble

5.10 Good granite stone was available in Sunkesala valley, about two miles (3.2 km) upstream of the dam. To start with, some quarries were opened by removing the overburden departmentally. Later, this work was entrusted to a dozen contractors on the job work system. The stones were blasted by explosives i.e , by dynamite and also by gunpowder. In practice, blasting by gunpowder was more effective, since the rock was just cracked to break it to sizeable stones for masonry work, whereas by dynamite the rocks were shattered and there was much wastage due to rocks crumbling to small pieces which could not be utilised. Drilling operations were carried out by contractors by compressed air with jack hammers and also by hand drilling. The average daily out-turn was 3115 cu m and a peak out-turn of 3540 cu m. was achieved. For supply of rubble a fleet of 100 trucks was deployed. The capacities of the trucks varied from 7.14 to 10.20 tonnes. About 25 per cent of the fleet belonged to the department and the rest were employed by the contractors. Fresh quarries were opened on the northern side of the dam at distances varying from 10 to 13 km for supplementing the stones from Sunkesala quarries. The new quarries from Bandala Karva were not in the submersible area.

5.11 The blasted stones were manually loaded into lorries at quarries, brought to dam site and were dumped manually on the earth platforms prepared on the upstream and downstream side of the dam and adjacent to the blocks. Small stones were lifted by individuals singly whereas stones from 0.03 cu.m to 0 09 cu m. were tied with iron slings and lifted by four persons called Jawalies with the help of a stout short wooden pole passing through the iron sling and carried on the shoulders of the Jawalies. Wooden scaffoldings consisting of ballies (Casurina poles) and bamboos fitted with steel bolts were utilised. The scaffoldings were of 1 8 metre width initially and were laid at a gradient of 2½ to 1 These were helpful for lifting to a height of 15 metres. Later, 2 75 m. wide scaffoldings were designed with a gradient of 3 : 1 These scaffoldings were used to lift the materials over a height of 72 metres. A mason helped by an assistant with necessary helpers depending upon the lift and lead involved for feeding the materials, gave a progress of about 3.80 cm of masonry in

a shift of eight hours. Rubble in trucks was unloaded on earth platforms, where mortar also was supplied on one side. Stones were supplied departmentally and also by job workers. They were weighed at weigh bridges for payment.

Sand

5.12 The first sand quarries were located in Peddavagu stream 16 to 19 km upstream of the dam in the submersible area in the bed of the river. The sand was dozed and collected in heaps and loaded into trucks by Eimco make loaders as well as manually. For supply of sand 45 lorries of 10.2 tonnes capacity were required of which 20 were engaged departmentally. As floods in the river were preventing quarrying operations at times, the sand was collected in the non-monsoon seasons from bed and stocked on the banks of the river above the flood level The quarries went under water for about 50 days in a year. They served for three seasons Later, the operations were shifted to sand quarries in the Hallia river, situated 21 to 32 km to the north of the dam These quarries served until the dam construction was completed The lorries worked round the clock and the full daily requirement was easily met.

Cement

5.13 Most of the cement required for the dam construction was supplied by the Krishna Cement Products Limited from the Macherla Cement Factory which was specially built in the private sector for the supplies to the dam The factory is located 24 km from the dam. The department laid a metre gauge railway track from Macherla to Lankamotu, about 2 4 km. downstream of the dam on the right flank To start with, cement was supplied in sixteen specially built bulk cement wagons. These wagons were fabricated in Public Works Department workshops at Hyderabad The bulk cement wagons unloaded the cement at the railway siding into a steel hopper, wherefrom the cement was rehandled, reloaded into bulk cement carrier trucks with pneumatic pumps and transported to the dam These carriers were of Thornycraft make, equipped with air compressors for lifting cement to a height of about 23 metres When the bins of the batching plants were full, the cement was stored in the standby storage silos. Three silos of one thousand tonne capacity each were constructed near the railway terminus at the foot of Lankamotu hill and one at each batching plant site. There were in all five cement silos of one thousand tonne capacity The bulk cement was supplemented by bagged cement, mostly in the early stages when cement silos were not ready Sometimes when the cement factory was on strike, cement was supplied from factories situated more than 320 km from the dam, i e from Shahabad, Mancherial and other factories.

In 1964, when the road bridge across the Krishna was washed away during heavy floods, it became difficult to convey cement from the right flank to the left. To start with, cement was conveyed in bags by ferrying across the river on punts hauled by launches. Within two months of the collapse of the road bridge, arrangements were made for pumping cement by pneumatic pumps through 15.25 cm. dia. G.I. pipes laid inside the 350 feet (190 m.) level gallery.

Surkhi

5 14 Twenty per cent of the cement in mortar was replaced by surkhi (finely ground burnt brick powder) for reducing the heat of hydration, to make masonry water-tight, etc. At first a quarry was located 2 4 km. at the downstream of the dam on the left flank in the Tiger Valley. These quarries served for two years and the operations were shifted to 12.8 km. north of the dam to Chilkurti quarries. In both the quarries, good clay was available for manufacturing surkhi. At first, ball mills were utilised for powdering the burnt clay and later centrifugal beaters were used. The surkhi was packed in jute bags of 1¼ cu ft. (0.033 cu.m) capacity and was conveyed to the work area by trucks. The surkhi was lifted to the bins of the batching plants by bucket elevators fed manually.

Coarse Aggregate

5.15 It was decided, as described in chapter VI in detail, to build the dam in full with masonry, eliminating concrete in highly stressed zones also. Even then concrete had to be used for covering the copper sealing strips, sides of the galleries, the spillway bucket, the rear face of spillway etc., and the requirement of aggregate had also to be planned.

Aggregates were manufactured with the help of a crushing and screening plant of 102 tonnes per hour capacity which was located at a level of 137.22 m. just above the Winget batching plant. Aggregates were crushed, screened and stocked in stockpiles in sizes of ¾″ (1.9 cms.) 1½″ (3.81 cms.) and 3″ (7 62 cms.). These were drawn from the stockpiles by an electrically operated belt conveyor located in an offtake tunnel under the stock piles. The flow of aggregates on the belt conveyor was regulated by hand operated gate chutes and the belt conveyor carried the aggregates in turn to different compartments of the Winget batching plant which was used for the manufacture of mortar as well as concrete

Manufacture of Mortar and Concrete

5 16 In the initial stages of the project, sand was being supplied from Peddavagu stream in the submergence area. A batching plant

with six mixers of one cubic yard (0.756 cu m.) capacity was erected at a distance of 600 yards (546 metres) Sand was supplied to stockpiles by lorries. An offtake tunnel was constructed under the stockpile to facilitate drawal of sand by electrically operated belt conveyors. The sand was made to drop on the belt conveyors by hand operated gate chutes and the belt conveyors carried the sand to the batching plant.

Another batching plant was located on the downstream side on the right flank of the dam to facilitate work on the right flank. This Plant had four mixers of one cubic yard capacity (0.756 cu m.) each and was located at a level of 38 5 metres. The batching plants consisted of Blawknox make mixers. They had a pneumatically operated batching system. The mixers of the tilting type were operated pneumatically.

5 17 With the increase of demand for mortar as well as for concrete, another batching plant was erected at a level of 85 metres on the left flank, on the downstream of the dam The plant consisted of four mixers of 4 c yd. (3 cu m.) capacity, with automatic weigh batching, electrically operated This batching plant was 21 m. high and were provided with four bins for coarse and fine aggregates and sand. It had a central compartment for cement. Under the bins were located the weigh batching equipment and the operator's cabin The next lower storey comprised of the four mixers. The bottom-most storey consisted of an unloading chute hanging from the roof. The concrete or mortar conveying equipments were brought under this chute for carriage to the site of construction.

The batching plant was procured from surplus machinery of the Hirakud project

The concrete was manufactured at the Winget batching plant The process of manufacture and supply of mortar and concrete was organised departmentally.

Conveyance of Mortar and Concrete

5 18 The mortar and concrete after manufacture were transported from batching plant to the dam site by three modes ·

(i) One mode was by one c yd. (0.756 cu m.) capacity tippers mounted on metre gauge trolleys hauled by Diesel locos. The mortar was unloaded into tipper-tubs which were hauled by the locos to the worksite and unloaded manually. The track for locos comprised of 20 lb (9 kg) rails laid at a ruling gradient of 1 in 100 This method was used on the upstream side during the initial stages of the project,

(ii) Another mode was by bottom opening 4 c.yds (3.03 cu.m.) capacity buckets mounted on flat cars running on 0.60 metre (two feet) gauge track and hauled by Diesel locos similar to the method mentioned above. The unloading of mix at worksite was with cranes.

(iii) When the rail track could not be laid to the worksite, the third method of conveyance by tipper lorries or by ordinary lorries, was resorted to. The tipper or ordinary lorry was brought under the unloading chute of the batching plant, for loading the mix. The mix was carried to the dam site where it was unloaded into a pan Manual labour was used for unloading the mix from ordinary lorries, which were non-tipping.

Placement of Mortar and Concrete

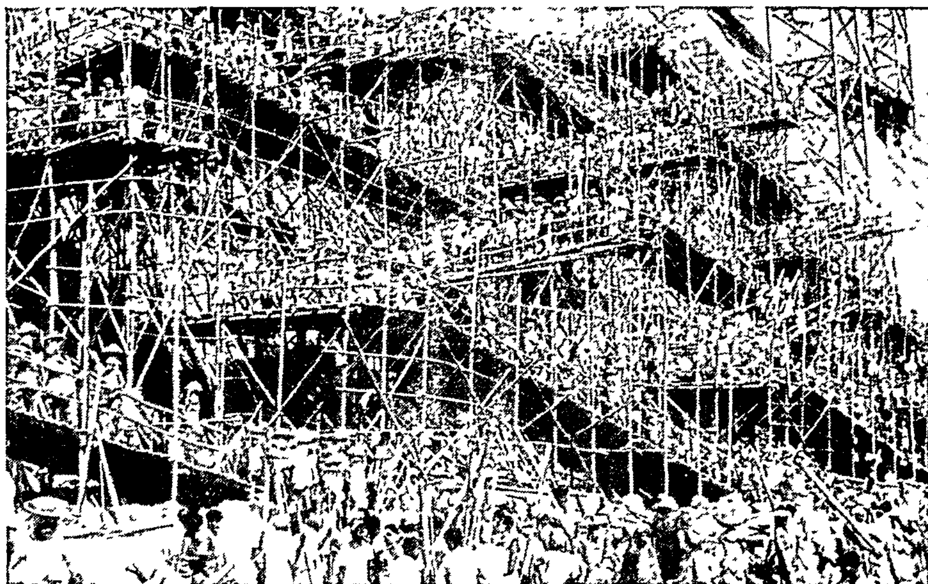
5.19 The Placement of mortar and concrete was by two methods :

(i) When the mix was unloaded at the dam site into a pan by the conveying equipment, the placement on the block was by manual labour. Scaffolding comprising of casurina posts and bamboos was erected for rubble conveyance, as described in para 5.11. The mortar was lifted by manual labour in iron pans of 1/4 c.ft (1/140 cu m). The mortar was supplied to masons on the top of the block who utilised it for the masonry This method of placement was predominantly used in the first stage of construction.

(ii) Another method was by cranes. In 1957, when the construction of the dam was started, the toe portion was built in concrete for some blocks. For placement of concrete, an earth platform was formed at a level of 83 2 m on the downstream side of the dam from Block 7 to 25. Over this platform, a 36 kg rail track of 6.10 metre width was laid and wheeled cranes, two Washington and two Clyde, were erected over the rail track These Diesel driven cranes were procured from Hirakud project, which was completed by that time. The Washington crane had an operating radius of 90 ft. (27 4 m.) and was capable of lifting a load of 10 tonnes, whereas the Clyde crane had an operating radius of 70 ft. (21 35 m) with a lifting capacity of eight tonnes.

5 20 The mortar and concrete, brought in bottom dump buckets from the batching plant by Diesel locos, were lifted by the cranes and unloaded directly on the masonry blocks The cranes were also utilised for lifting rubble filled in skips They were also used for erecting the penstock pipes and mono-tower cranes as will be described later This method of placement of mortar and concrete was used for the blocks on the left flank even in the early stage of construction.

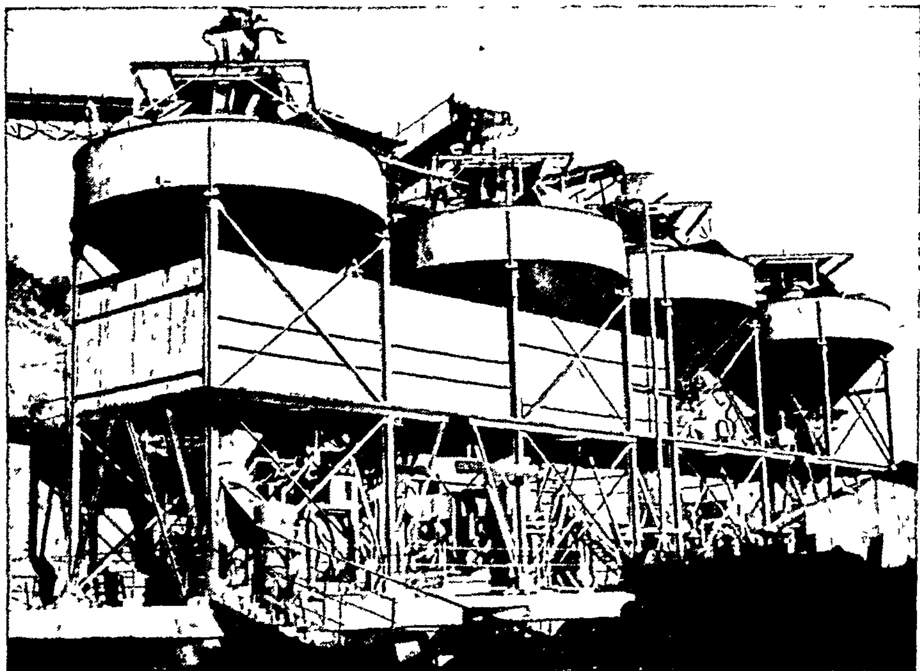
Washington Cranes unloading stones and mortar brought by light Railway (*Para* 5 4)



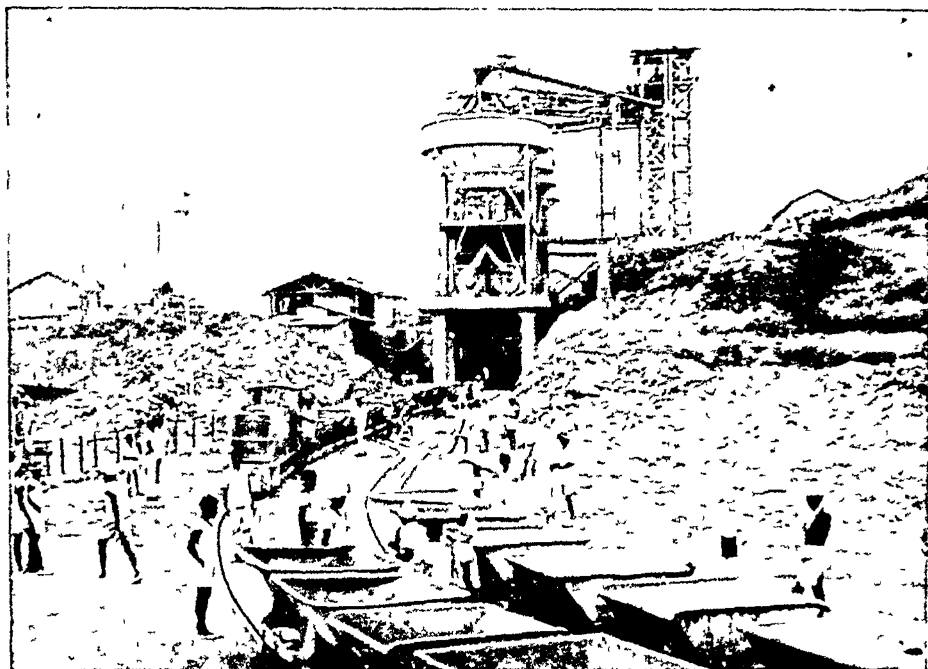
View of the Dam showing Scaffolding and Gangways—(*Para* 5 6)



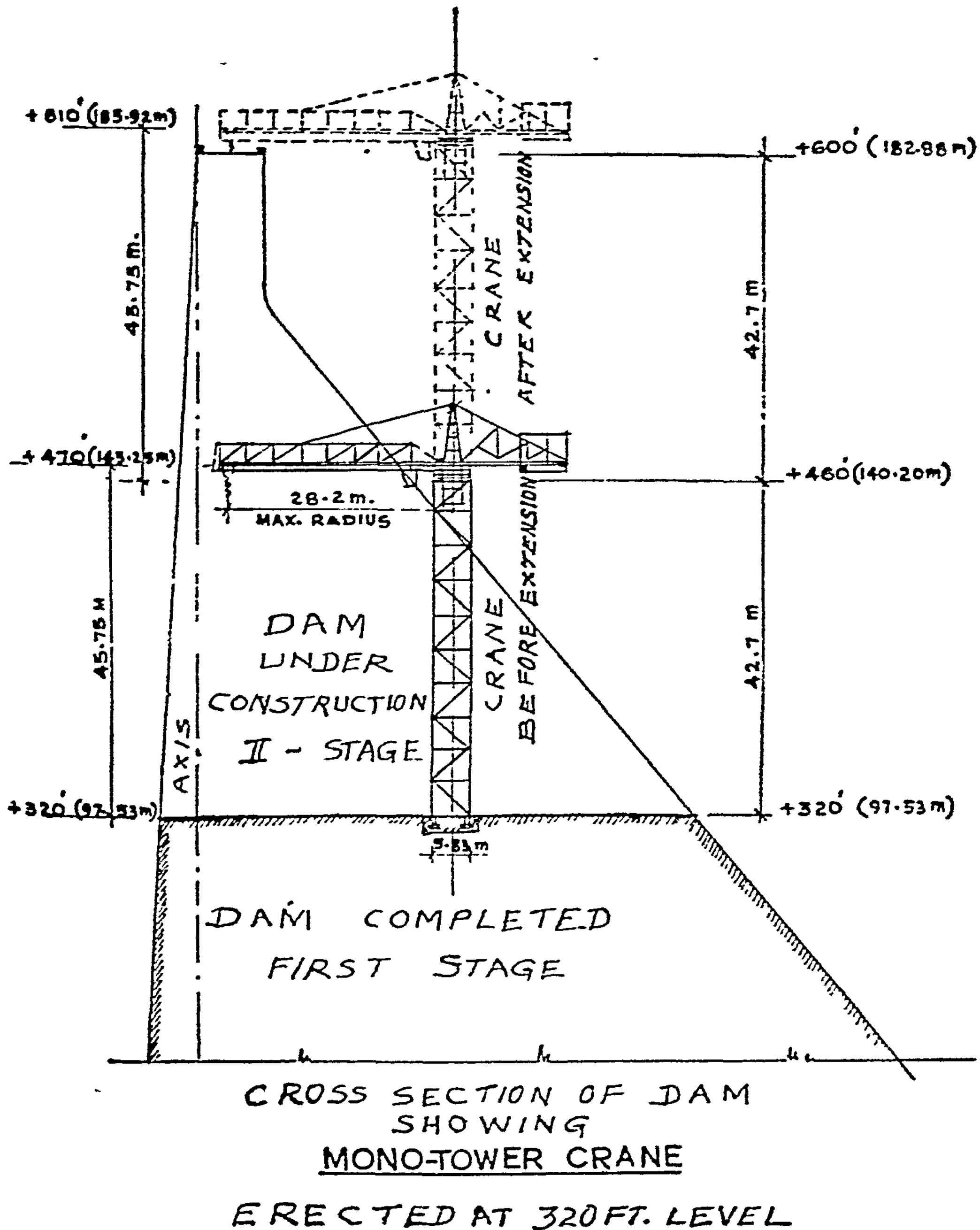
Jawalees lifting heavy stones with slings—(*Para* 5.11)



Blawknox Batching Plant at Left Flank, Mortar was conveyed through Tippers hauled by Diesel Locos—(*Para* 5 16)



Winget Batching Plant at Right Flank—(*Para* 5 16)



CROSS SECTION OF DAM SHOWING
MONO-TOWER CRANE
ERECTED AT 320 FT. LEVEL

Second Stage Construction

5.21 The first stage construction mostly by manual labour could be adopted up to a level of 103 metres by putting up scaffoldings with casurina posts and with bamboo matting over that. The second stage construction started with the erection of two mono-tower cranes on the left flank in blocks 18 and 22 at a spacing of 105 metres The transition from the first stage to the second was gradual, depending upon the availability of cranes and the progress of construction

Mono-Tower Cranes

5.22 The lifting of materials in the second stage was mostly by mono-tower cranes They lifted the materials directly on to the blocks and also fed the belt conveyors A mono-tower crane may be briefly described as an electrically operated fixed hammer-head crane It has an operation radius of 28 2 m with a mobile hoist on one side and fixed counter-weight on the opposite side. The crane is capable of lifting, at a radius of 28 2 metres, a load of 8 metric tonnes with a mobile hoist. The hoist is designed for a wind pressure of 155 kg per sq metre, and for acceleration, retardation and swaying forces The boom of the crane is horizontal. Vertical motion of the boom is not possible. The crane rotates through 360° in a horizontal plane. The hook is capable of raising and lowering through a distance of 61 metres at a speed of 76 2 metres per minute The crane is designed to revolve and lift or lower simultaneously. A novel feature of the crane is that the jib of the crane can be lifted to any required height without dismantling any part of the crane. Initially the cranes were erected with a lower height of 27.5 metres. The electric power used was 3 phase 50 cycles 400/440 volts Cost of each crane was Rs. 311,000 out of which the cost of the imported components was Rs 170,000 The feet or the mast angles of the crane were designed to rise from the dam with a foundation of three metres into the masonry As the masonry went up, the legs of the crane went buried With the raising of masonry, the boom had to be raised. The raising was done by means of an erection device The erection device consists of a trestle piece and jacks The entire jib is raised off the mast angles of the tower When it is raised by 9 15 metres, additional mast angles are added and the load of the crane is transferred from the erection device to the mast angles Thus, the crane could at one stage be raised to a height of 9 15 metres. Thereafter, this process could be repeated. The free vertical height of the mast is to be restricted to 45 75 metres The steel structure for the mast was fabricated indigenously and the entire erection was done departmentally. The cycle of operation of the crane varied from six to eight minutes for lifting each bucket of mortar of three cubic metres volume. The cranes were also used for lifting rubble.

In all 13 mono-tower cranes were erected on the non-overflow section at about 73-metre intervals from levels varying from 105 to 148 metres. Three cranes were erected in the spillway and one in the rubble yard on the left flank for lifting rubble. A mono-tower crane could give a progress of 56 tonnes of mortar or rubble in an hour. This works out to a progress of lifting 157 cubic metres of mortar in a period of eight hours to build 336 cu.m. of masonry.

Trestle Bridge

5.23 In the second stage of the construction, due to limitations in the height of the lifting materials and the boom radius of the cranes, a trestle bridge became necessary. The materials were brought on trucks or by railway over the trestle bridge to facilitate the cranes to lift the materials. Thus, in the second stage of the construction for lifting the materials mechanically, a trestle bridge had to be provided to lift the materials up to the top level of the dam at level of 184 5 m. The trestle bridge was built at a level of 128.10 metres, and approach roads were built on either flank of the dam to convey materials to this elevation. As per the original proposals, a long trestle bridge, 1092 metres long, was proposed with a width of 10.67 m. to span from the left to right flank. For the construction of the trestle bridge in the spillway, alternate blocks were proposed non-overflow in which mono-tower cranes were to be erected. In the alternative spillway blocks, the bridge was to be removed every year. This process was time consuming and costly. Further the steel required for the bridge was of the order of 10,160 tonnes. It was difficult to procure this The proposal estimated at Rs 9.4 millions, was also costly. So it was shelved in favour of leaving ledges in masonry on the flanks and putting up a short length of trestle bridge in the spillway. Thus on flanks, the steel trestle bridge was changed over to a masonry ledge.

5 24 Hence, it was decided to construct a masonry ledge of 7.32 metres width on the left and right non-overflow rear faces of the dam and limit the length of the trestle to 146 m in the spillway portion from block 25 The width of this trestle bridge of short length was kept at 7 32 metres as against the 10 67 metres formerly proposed. With this modification, there was a saving of Rs. 1 2 millions.

Lifting of Rubble

5 25 In the scond stage of the construction, the quarries in the bed of the Sunkesala valley, situated 41 to 81 km from the dam, were submerged and the rubble was brought from Bandala Karva quarries, 13 to 16 km north of the dam site Quarries were also opened on the right bank near Anupu, 13 km to the west of Vijayapuri South. It is always

advantageous to have a minimum number of quarries The main quarries were situated on the left flank of the Krishna But when the connecting bridge between the left and right flanks snapped away due to floods in 1965, quarries had to be opened on the right flank as it was not possible to feed the right flank blocks of the dam from the left flank quarries.

Quarrying of Stones

5 26 Blasting operations were done by pneumatic drilling Compressed air and jack hammers were supplied to the job workers on an hourly hire basis Stones were blasted with gelatine and electric detonators Ordinary detonators were also used. For quarrying stone, hand-drilling was also resorted to and gun-powder used as explosive. By using gunpowder, there was no shattering effect on the rocks as in the case of using gelatine. By causing minimum cracks and then by hand breaking, economy was observed. Labour camps had to be constructed for the labour nearer to the quarries Every job worker had his own quarry. There were nearly thirty quarries operating simultaneously Women also worked in the quarries and assisted men in separating spalls from stones. Stones were loaded into steel skips manually. The skips, which were of 4.3 cu m capacity, weighing seven tonnes, were loaded with the help of a crane into lorries The bodies of the lorries were specially designed to carry these skips. The lorries conveyed the stones from quarries to the dam over the ledge and over the trestle bridge in a part of the spillway.

5.27 Lifting the stones into skips with mobile cranes became costly as the quarries were scattered and the cranes which were of 25 50 metric ton capacity cost Rs. 4,50,000 which was rather high. There were six such cranes of Lima make operating at different places The cost of this crane operation per cubic metre of stones worked out to Rs 5 6 This method was adopted from 1960 to 1963 It was suggested that sixteen more of such cranes be purchased to cope with the progress. There was difficulty in getting foreign exchange for the purchase of additional cranes While trying to solve this problem, a novel idea presented itself for avoiding lifting the skips into lorries by cranes

A Novel Method to Eliminate Cranes

5 28 A two-foot (0 61 metres) gauge railway line was laid near the rubble yards, with a high platform, close to the dam within half a mile (0 8 km) The platform was eight feet (2 44 metres) above the level of the railway line The elevated platform received stones from the quarries brought in the lorries directly without skips Skips were mounted on flat trolleys which were operating on the railway line and were lined up in rows Three railway lines parallel to the elevated platform were laid for shunting the loaded and unloaded skips The rubble was

loaded from the elevated platform into the skips manually. Sometimes when the platform was not full with rubble, the lorries directly unloaded the stones into the skips on flat trolleys.

5.29 Five Diesel locos of capacities varying from 40 to 80 H.P., were used for hauling the flat trolleys to the 128 m. level road on the rear dam face, wherefrom they were picked up by the mono-tower cranes. Similar arrangements were repeated on the right flank of the dam for conveyance of rubble. This changeover was very economical. There was a saving of Rs. 5.6 for every cu metre of rubble. The savings effected by this method was nearly Rs. 10 million. This method eliminated rehandling of rubble by cranes.

Supply of Sand

5.30 For the second stage of the construction, the entire sand needed was brought from the Halia river with a lead of 29 to 32 km. The sand was directly loaded into lorries by manual labour. After every flood, there was adequate regeneration of sand in the river bed and thus there was no shortage. As progress by manual labour was good, there was no need for the employment of mechanical loading. In all 40 Leyland trucks of seven ton capacity each were engaged for the sand supplies. Sand supplies were done partly departmentally and partly by contractors.

Supply of Surkhi

5 31 The entire surkhi was procured from Chilkurti kiln. The bagged surkhi which was brought to the dam by lorries, was unloaded and emptied in a bin and was lifted to the bins of the batching plant by bucket elevators.

Batching Plants at Higher Level

5.32 For the second stage of the construction, the existing batching plants had to be re-erected at higher elevations On the left bank, a batching plant was built at 129 metre level. The plant consisted of six mixers of one cubic yard (0.75 cu.m.) capacity.

On the right bank, at 156 metre level, a batching plant of four mixers of 1/2 cubic yard (0 38 cu.m.) capacity was set up. The Winget batching plant on the left flank remained in operation till the completion of the dam.

Floating Batching Plant

5.33 In the final stage of the construction, when the water level in the reservoir rose high, floating batching plant with two mixers of one cubic yard (0.75 cu.m.) capacity was set up on the foreshore of the left bank

within 200 metres of the dam. The batching plant was mounted on a punt and the feeding of raw materials was done from the shore manually. The mortar was collected into buckets of 3 cu yd capacity which were mounted on a separate punt and hauled by a Diesel driven launch. The mortar from the bucket was conveyed to the upstream edge of the dam, where the monotower cranes picked up the buckets This system effected good savings in leads and lifts, but during the months of May and June, when winds were strong, the punt could not operate and the work had to be suspended.

Transhipment by Belt Conveyors

5 34 Huge quantities of mortar and concrete had to be placed in the spillway section where there were no cranes for direct dumping In the absence of ropeways and trestle bridges, the problem was effectively solved by a system of belt conveyors The width of the spillway is 419.6 metres Belt conveyors were erected for feeding concrete and mortar from both flanks of the spillway The conveyor system consisted of a flat rubber belt on rollers and was erected on steel trestles over the spillway 331 metres and 340 metres from the left and right end of the spillway respectively, were covered by belt conveyors. At the feeding end, the concrete buckets lifted by cranes were unloaded in hoppers and the flow of mix was regulated to the belt conveyor with hand-operated chutes At the supply end, the conveyors were provided with revolving chutes and elephant trunks, for delivery of the concrete into chutes radiating in different directions, similar to water flowing through field channels When the chutes could not directly dump at the work place, the concrete was manually rehandled As the spillway was raised, the trestles of the belt conveyors were buried under concrete. The conveyors were lifted by adding extension pieces to the columns of the trestles. Each belt conveyor could supply as much as 68 cu m of concrete per hour, but it was difficult to arrange for this progress continuously due to the time taken at the feeding end and the arrangements requied for changing the chutes at the supply end.

Transhipment by Walkway

5 35 In the final stage, for manual rehandling of mix, a walk-way, 1.8 metre in width, over trestles of 9 metre height was provided at a level of 180 metres which was higher than the highest flood level The walkway connected the left and right flanks over a length of 420 metres to facilitate raising the intermediate piers of the spillway. The walkway also served for transhipment of materials and for laying the air and water lines It was built against gales and winds of high velocities in a record time of 45 days without a single accident. But for the walkway, the entire programme of raising the spillway would have gone behind schedule by one

season. This has been acclaimed as a great engineering feat by the press and the public.

Other Construction Equipment

5 36 Other construction equipment such as excavators, scrapers, and dozers were used , but these were utilised mostly for formation and maintenance of earthen platforms, approach roads and other emergent gap filling works. The equipment was also used for rehandling aggregates etc., when necessary.

The earth moving equipment was only partly used for the formation of earth dams as the equipment had priority task for river diversion by putting up earth bunds. Therefore, part of the earth dam was entrusted to contractors who utilised lorries for transport. Compaction work was done departmentally.

RESUME

5.37 Concrete was also lifted manually even against a height exceeding 92 metres Though this system was not profitable, it provided employment for thousands of workers and did not require any equipment except high scaffoldings. This method was restricted to a limited number of blocks, which were too remote for feeding with other methods and which required emergent progress.

Thus a diversified plan was adopted for the haulage of materials and mortar from their source of production to the actual area of construction to suit the progress, stage, and reach of the masonry block in progress, ensuring optimum speed, ease and economy The entire plant layout was designed, planned and constructed by Indian Engineers, assisted by the Central Water and Power Commission, New Delhi Thus the world's largest masonry dam has been built with the least machinery and equipment, and employing the maximum man power, a technique which is excellently suited to conditions in India and other developing and densely populated countries.

CHAPTER VI

CONTROL OF THE KRISHNA FLOWS

The diversion of the Krishna during the construction period required imagination, courage and a careful study of hydrology for economic planning of the flows The probable river flows in the various seasons of the year and hazards during floods had to be taken into account. The variation in the discharge of the river is very wide ranging from about 60 cumecs in summer to as much as more than 30,000 cumecs in the monsoons The river diversion works required careful studies of the flows in the river in various seasons. The best and reliable method was to study the data of gauges and discharges at the gauging station, 180 km below the dam site, at the barrage across the river near Vijayawada Daily discharge records are available from 1894 onwards The drainage basin of the river is chiefly under the influence of south-west monsoons and, therefore, the river is in floods from June to October In living memory, the highest flood recorded at Vijayawada was 33,100 cumecs on September 30, 1964 This quantity is more than twice the maximum discharge of the Nile in Egypt. Before building the Nagarjunasagar dam, the maximum recorded discharge of the river was 30,000 cumecs in 1903 at Prakasm Barrage near Vijayawada

The discharge in the river decreases rapidly after October After October, the dry weather flow used to be as low as 3 cumecs, prior to the construction of the Tungabhadra dam in 1956.

The lower reaches of the Krishna are subject to the influence of the north-east monsoon also, from October to December This rainfall is concentrated along the coastal belt for about 100 km from the Bay of Bengal. All the records of the flows were studied and schedules of construction drawn up for the diversion proposing coffer dams, diversion sluices and a tunnel in various stages of construction

A study of the hydrographs of the Krishna at Vijayawada over a period of 60 years (1894-1954) showed that the river flow is generally high during the period June to October and that floods of 14,000 cumecs occurred 28 times, floods of 20,000 cumecs, five times, and a flood of 28,000 cumecs, twice Further, by the end of December, the discharge in the river comes down steeply to 140 cumecs, and then dwindles down to 14 cumecs, on an average by the end of March This shows the inherent difficulty of controlling the river flows during the construction.

In building the Nagarjunasagar dam, not only had the river to be controlled but it was also essential to ensure adequate flows downstream to cope-up with the requirements of existing irrigation in the delta for an area of half a million hectares. Untimely supplies would be detrimental to the needs of irrigation and would thus result in loss to the millions of farmers and to the nation at large The construction had therefore to be planned and programmed in such a way that the needs of the first and second crops below Prakasam Barrage were met without any interference and that the work on the construction of the dam progressed speedily without any hindrance.

Masonry Coffer dam

6 2 Work on the dam was divided broadly into two periods , monsoon and non-monsoon The main work of the diversion of high flows, for construction during the monsoon period, was achieved by constructing a masonry coffer dam on the left flank.

For the purpose of the initial diversion of the river, the bed was divided into three parts ·

(i) Left non-overflow portion covered by a masonry coffer dam wall.

(ii) Middle portion to be tackled by high and low blocks with the assistance of earthen diversion bunds to be put up with heavy machinery operations.

(iii) Right deepest course to be tackled by earthern diversion bund after diverting the flow through high and low blocks.

To tackle the bed of the river for the foundation of the dam, the first coffer dam was planned to be started in the non-monsoon period of 1956 , and the work was begun in November 1956. A masonry coffer dam was started on the left flank covering about one-third the width of the river. The masonry was built in quartizite rubble in 1 : 8 cement mortar to 85.35 m level roughly 12 m. above the bed level. The first layer of the coffer dam was laid in a richer mix of one cement and four sand. The coffer dam was aligned so as to utilise as far as possible the highest rocky outcrops avoiding depression and deep pockets. It was considered adequate for a normal flood of about 20,000 cumecs. It had enabled the left portion of the dam and the working area in the upstream and downstream side of the river free from monsoon flow of the river. It was built in a record time of 88 days at a cost of Rs. 1.56 million The unit cost of masonry per cu. m works out to Rs 21 which was the lowest rate of masonry among contemporary works carried out in India.

(a) Seepage Through Coffer Dam

On July 8, 1956, the water level in the river started rising When the author was inspecting the coffer dam at 1 p m. with the rise of the water a hissing sound was heard. The watchman reported that the sound was being created by frogs. When a close examination of the junction of the masonry coffer dam with the earth flank was made with a torchlight, it was seen that 12 mm. diameter jet of water was coming into the coffer dam In a hydraulic structure, the junction points of masonry and earthwork are the weakest and require careful treatment. The coffer dam being a temporary structure, due care was not taken in raising the earth flank, foreseeing the dangerous consequences of this undesirable leakage. A scraper unit was deployed within half an hour. The scrapers brought impervious soils and dumped them on the upstream side of the affected place. A bulldozer pushed the dumped earth to the correct position. The dumping operation of the earth took two hours The leakage was completely sealed By that time, water surged into the coffer dam for a depth of 1 2 m and the jet of water caused enlargement of the seepage hole from a small diameter of 12 mm to a big aperture of 90 cm., within a couple of hours Any delay of a few minutes would have caused irreparable loss. But for the timely decision and prompt action, one season of the dam construction would have been lost. Though coffer dams are purely temporary structures, their failure can retard progress for a season Therefore, particular care and vigilance is essential, especially, when these temporary structures have to face rising floods for the first time after their completion.

(b) Floods in August 1956

Flood warnings were being received by express telegrams from the gauge readings of levels of the Krishna from the anicuts 160 km. above, from Pragatur and Sunkesala. On August 6, 1956, telegrams were received from the above gauges, warning of a rapid rise in the river due to abnormal rains in the catchment. The corresponding discharge at the dam site, was expected to be over 22,800 cumecs. The masonry coffer dam was not designed for this flood and would have been over-toppled To deal with this emergent and dangerous situation, the coffer dam was raised by 1.5 m , from 83 82 to 85 32 m. level with brick masonry in cement mortar (one cement and four sand), as bricks were readily available The raising of the masonry was completed in 24 hours round the clock It was on the third day after the wall was raised that it was subjected to floods. Meanwhile, the downstream side of the wall was strengthened by raising earth work with the help of a scraper unit. This was necessary for back pressure. The heavy machinery operations were also completed before the coffer dam wall was subjected to the heavy floods There was no necessity to raise the downstream portion of the coffer dam as there

was a drop in the flood water in this reach. The coffer dam was built with a uniform top level of 85.32 m.

The masonry coffer dam was subjected to the first high floods of 24,300 cumecs on August 10, 1956. It began to seep heavily where the proportion of mortar was lean ; (one part of cement and eight parts of sand). At some places, jets of water of the size of 2.5 mm.diameter started shooting. With this heavy seepage of water, it was feared that the coffer dam would be flooded, defeating the purpose for which it was built. But surprisingly the experience proved different. The interstices of the lean mortar of the masonry went on arresting the colloidal clay of the silt laden water of the river The masonry gradually became safe against seepage in the course of three days. The maximum pumping of water from the coffer dam did not exceed 1.7 cubic metres per minute. A quantity of 0 90 m depth of water collected due to the seepage in the first three days This was pumped out in two days and excavation of foundation within the coffer dam was resumed when the river was in floods.

The above experiences vividly brought out the importance of vigilance and the heavy machinery that should be kept in readiness as a standby before attempting coffer dams and diversion of large river flows. In this particular instance, four scrapers and two bulldozers were deployed and the lead involved in earth work was 0.8 km.

Diversion Through Alternative Low Blocks

6 3 Three openings of 3.05 m. × 3.05 m. were proposed in each of the blocks 43, 45, 47 and 49. Each block was expected to discharge 140 cumecs. Two such blocks were required to take the summer flow of 280 cumecs ; two more were also provided Each block was provided with three bulkhead gates of size 4 876 m. × 5. 643 m. to operate in the openings provided between the concrete piers in front of the blocks. When blocks 43 and 45 were closed with gates, blocks 47 and 49 were used for diversion and masonry raised in blocks 43 and 45. The dam towards blocks 43 and 45 was cordoned off with earth bunds. Earth coffer dams were repeated alternatively and the masonry was raised, building the low and high blocks, as described above This method was tried for one season and was shelved due to the following drawbacks.

(i) It was difficult to make the shutters leak-proof, any small leakage interfered with the construction of masonry.

(ii) The shutters were required to be removed and carried to safe places before the floods Else, they would be subjected to damage during the floods.

(iii) Culverts had to be constructed on the downstream side of all the four low blocks, as an approach was necessary from the downstream side for feeding the material for the construction The decking of the culverts had to be removed in each season to safeguard against floods and they had to be re-laid the following season :

(iv) Each high block required two wing walls at the junction of the abutments of culverts, to train the floods and to safeguard the approach to high blocks getting scoured

(v) The piers and abutments of the culverts were getting damaged during the floods

(vi) Openings left in the blocks for diversion of the floods were becoming construction joints and required careful filling

On account of the above disadvantages, the pattern of high and low block construction for river diversion is not recommended for future high dam construction This method could be adopted for small discharges

While the river was flowing through low and high blocks, the right bank portion of the river, which was the lowest in level, was made dry by an earth coffer dam and the foundations were tackled during the period 1960 to 1962

Diversion Through Construction Sluices

6 4 Before diverting the river through construction sluices in 1963, the lowest portion of the river in block 41 had to be closed The entire river was flowing through block 41. For this purpose an earth coffer dam was thrown covering the low gap The closure of this earth coffer dam presented a very difficult situation, where a high velocity current exceeding 20 ft per second was scouring the earth bund before closure. To check this stupendous flow of 1,000 cusecs, huge stones of five to ten tonne weight were brought by heavy dumpers and pushed by bulldozers into the stream Lifting heavy stones by shovel, carrying by dumpers and unloading are shown in the photo at page 121.

Construction Sluices

6 5 In 1962, six diversion sluices of 3 05 m diameter were proposed. The sluices were tapering to 2 74 m. dia on the downstream side with their centre line at 82 30 m. level i e. 7 62 m. above the bed level of the river. Gates were provided on the upstream side for plugging the sluices This work presented very complicated problems and heavy work load had to be tackled in the shortest time The engineers had to work round the clock and face problems with anxieties similar to operations in a war front.

The work required reinforced concrete of 31,388 cu. m. involving 4,273 sq. m. of shuttering and 851.4 tonnes of reinforcement. After having taken the above decision, there was hardly time to call for tenders. The value of the work was estimated at Rs 6 million, to be accomplished in two months; and no contractor was prepared to take up the work on nomination due to limited working time. This challenging work was taken up departmentally and was organised in three shifts. The shuttering planks were manufactured in the departmental workshop of the dam and simultaneously in the Government and private workshops at Hyderabad. Steel planks were not available. Some old railway wagons were lying in the state workshop. The plates of the wagons were flame cut and the shutters were manufactured. Eighty carpenters and fitters were employed on daily wages, apart from the departmental staff of 30. A field workshop was set up within 90 m. of the work site in the bed of the river. Their boarding arrangements were made from the Annapurna cafeteria which was running at the work site.

Care was taken that the labour did not drink the river water which was subjected to pollution. Therefore, drinking water taps were extended to the work site. The Civil-Surgeon, Dr. T. Rangaiah gave the maximum co-operation to check up the health of the persons round the clock. He was vitaminising the staff; and one multivitamin tablet was given to each of the workers who had to toil more than eight hours continuously for several days. Mr. S. V. Sastry, Mr. P. Krishnam Raju, Mr. A. V Subba Raju, Mr. R. Venkateshwar Rao and Mr. A. Ramchandra Rao were the Assistant Engineers who were managing the work in various shifts round the clock.

Concrete was brought from the batching plants in 3.05 cu.m. buckets mounted on lorries and was poured with P & H cranes which could handle them at a radius of 15 m. In difficult reaches the concrete was rehandled manually.

This emergent work of complexity involving 31,388 cu.m. of reinforced concreting, 4,723 sq. m. of shuttering and 851.4 tonnes of reinforcements, was completed in 59 days and the structure was finished at a cost of Rs. 4.2 millions with a saving of Rs. 1.8 millions. This is the biggest departmental work ever organised and accomplished by the project in a record time at the lowest cost The unit cost of reinforced concrete of this complicated and difficult task worked out to Rs. 134.84 per cu m. which is the lowest rate of any contemporary work in India

The construction sluices served to divert the summer flows of the river in two seasons of 1962 and 1963. They were plugged in 1964, when the flows were diverted through a tunnel of 8.13 m. diameter constructed on the left flank.

Crossing the River during Construction

6 6 A reinforced concrete bridge with 22 spans of 19 68 m each was constructed in 1959, 1½ km below the dam site for communication across the river. An unprecedented flood of 34,000 cumecs threatened the dam under construction on September 30, 1964. This sudden gush of water over the incomplete spillway hit with a heavy impact obliquely against the piers of the road bridge. Out of 22 spans, 15 were washed away. Traffic was restored over the bridge by putting earthern ramp which served for one year. In the following years the earthern ramp was washed away in floods and was subsequently abandoned, being costly to rebuild it. In its place fair weather roads were built during non-monsoon seasons on the downstream side of the dam Pedestrian traffic during monsoons was conducted through the gallery. Cement also was being pumped through the gallery. In the last stage of the construction, a walkway of 1.8 m. width was built on the dam. It was dismantled with the completion of the spillway bridge over the dam.

Plugging of Construction Sluices

6.7 The work on the plugging of the construction sluices was taken up in April 1965 after the completion of the tunnel. These six diversion sluices with the centre line at a level of 82.30 m two in each of blocks 43,45 and 47 were provided with single steel shutters of size 4.88 m. × 5 33 m. outside to outside, weighting about 6 tonnes As these gates, were designed for only 5 33 m head of water, they were strengthened to withstand a head of 12 19 m of water since the water level was expected to go up beyond 91.44 m. during the plugging of the sluices. After strengthening, the weight of the gates increased to about 12 tonnes. The conveyance and erection of these gates posed a problem as they could not be handled by Washington or Monotower cranes. Hence, winches and chain blocks were employed.

As the downstream face of the dam was covered with scaffoldings in blocks 43,45 and 47, the gates had to be conveyed from the upstream side. Out of the discharge of 142 cumecs in the river at dam site, contributed mostly by the power releases of the Tungabhadra dam, about 85 cumecs were diverted into the K C. Canal, leaving a balance of 57 cumecs. However, for the purpose of planning the work at Nagarjunasagar dam site, it was assumed that 85 cumecs would be the discharge to be encountered.

The work of plugging was organised to be carried out in three stages as follows :

(i) *First Stage*

An earth bund was formed in April 1965 by employing machinery upto block 44 and water was diverted to flow through the sluices in blocks

45 and 47. As the seepage was appreciable, a secondary bund was formed to reduce the seepage water going into sluices in block 43. This reduced the seepage considerably and the little leakage that was there was let out through a small 15 cm dia. opening made in one of the shutters and the pipe inserted in the header wall extending to 3 05 m. downstream of the upstream face of dam in the barrel. The shutters of the sluices were then lowered, liner-lugs were gas-cut and preliminary arrangements were made for concreting after chipping, cleaning, etc. The gates were to be handled from the upstream side. The road upto block No 42 was repaired and made use of. Beyond 42 block and upto 47 block (i e.) for a distance of 110 m. the gates were conveyed with the help of a gantry crane rail fixed high up at about 96 m. level at a distance of about 0 9 m from the upstream face of the dam and using the travelling 10 tonne chain-blocks to lift up the gates vertically The horizontal movement of the gate was effected by operating two winches stationed on 47th block. All necessary precautions were taken to see that the gates could be lowered properly.

In the first stage, plugging of sluices in block 43 was done for 10.67 m. length covering three linear lugs out of a total sluice barrel length of 80 47 m. This was found to be abundantly adequate by calculations to withstand the water pressure that was likely to be built up in the 1966 monsoon season. Concreting work was done in two instalments. First concreting was done upto the centre line elevation of the sluice and left for curing and aeration for one day. The balance was completed thereafter for 10.67 m. length of the barrel.

(ii) *Second Stage*

The shutters of sluices of blocks 45 and 47 were closed simultaneously and the water was cut off by a ring bund formed on the upstream, as in the case of block 43. Plugging operations as described above were repeated During the first stage of operations i.e , while plugging sluices in block 43, the four sluices in blocks 45 and 47 could discharge 85 cumecs with the water standing at 83.82 m. level. During the second stage of operations, the water level was steadily building up and the operations were programmed to be completed before it could reach 91 4 m level. Later on, after the plugging operations were completed, water was allowed through the diversion tunnel at 91.4 m level. Here it is to be appreciated that we had to reckon with the possible inflow, the time it takes to build up to 91.4 m level and the time needed for forming the earthern coffer dam or ring bund on the upstream and plugging operations. Suitable earth moving and hauling equipment etc., had to be deployed on this work. The work was organised round the clock.

It was estimated that it would take about 17 days to build up the reservoir level to 94 18 m at which level the inflow of 85 cumecs. would be equal to outflow through the 91.4 m level tunnel. A flood in the river was expected during the third week of May by which time the dam was programmed to be completed upto 112 78 m level which would provide an absorbing capacity of 673 million cu.m.

(iii) *Third Stage*

Concreting of the balance barrel length of these sluices was done in the summer season of 1966. This presented no problems Contact grouting was done later on in the plug concreting with the help of the grout condulets left in position

The concrete used for plugging was of rich proportion, of 281 kg /sq.cm. strength, mixed with water-proof chemical 'Acco-proof'. The concrete from the winget batching plant from downstream was conveyed by lorries to the sluice exit and thereafter it was carried by headloads through the barrel The pipes provided for draining seepage water were plugged and grouted later on by connecting with grout pipes on the downstream side.

High level Diversion Sluices Omitted in Favour of Diversion Tunnel

6.8 As the operation of the construction sluices at 82 3 m level would be very difficult at high heads, high level sluices were proposed in the dam between 102 10 m and 129 5 m levels to facilitate plugging of 82.3 m level construction sluices and to serve for the final diversion. One of the proposals considered was to provide 18 sluices at 129 5 m. level and 8 sluices at 102 10 m. level. But the sluices at the level of 102 10 m. would have to be constructed, including the installation of gates, by May, 1964 and these sluice blocks had to be raised to 141.74 m level by that time. The sluices would have to be designed for operation with the full reservoir head i e, 79 25 m.

Tenders were called for the river sluices gates. Examination of the tenders revealed that the gates would be supplied only by the end of 1964 and that as such it would not fit into the construction programme Further the tender rates for the gates were much higher than the estimate rates. Moreover the construction of 18 river sluices at 125 m would have to be done during the period January 1966 to June 1966. In this period the spillway would also have to be raised by 30 5 m. i e., from 124.97 to 155 47 m. levels This would not be feasible and was likely to delay the completion of the dam.

Taking all these factors into consideration, it was felt that alternative arrangements to the river sluices were necessary. After examining several

alternatives, the proposal was finalised for providing a diversion tunnel of 8.23 m. dia. horse shoe shape with invert at 91.4 m. level, crossing the left earth dam at 5.578 km. i.e., 76 2 m. from the end of the masonry dam. The ground level at the crossing is about 163.07 m. level and the granite rock is at 128.02 m. level. The 91.4 m. level tunnel would be entirely in granite and would be provided with two vents of 3 048 × 7.620 m. and fitted with gates. The tunnel would discharge 700 cumecs, at a head of about 15 m. i.e., with the reservoir level at 106 68 m. The tunnel entry would be plugged later on.

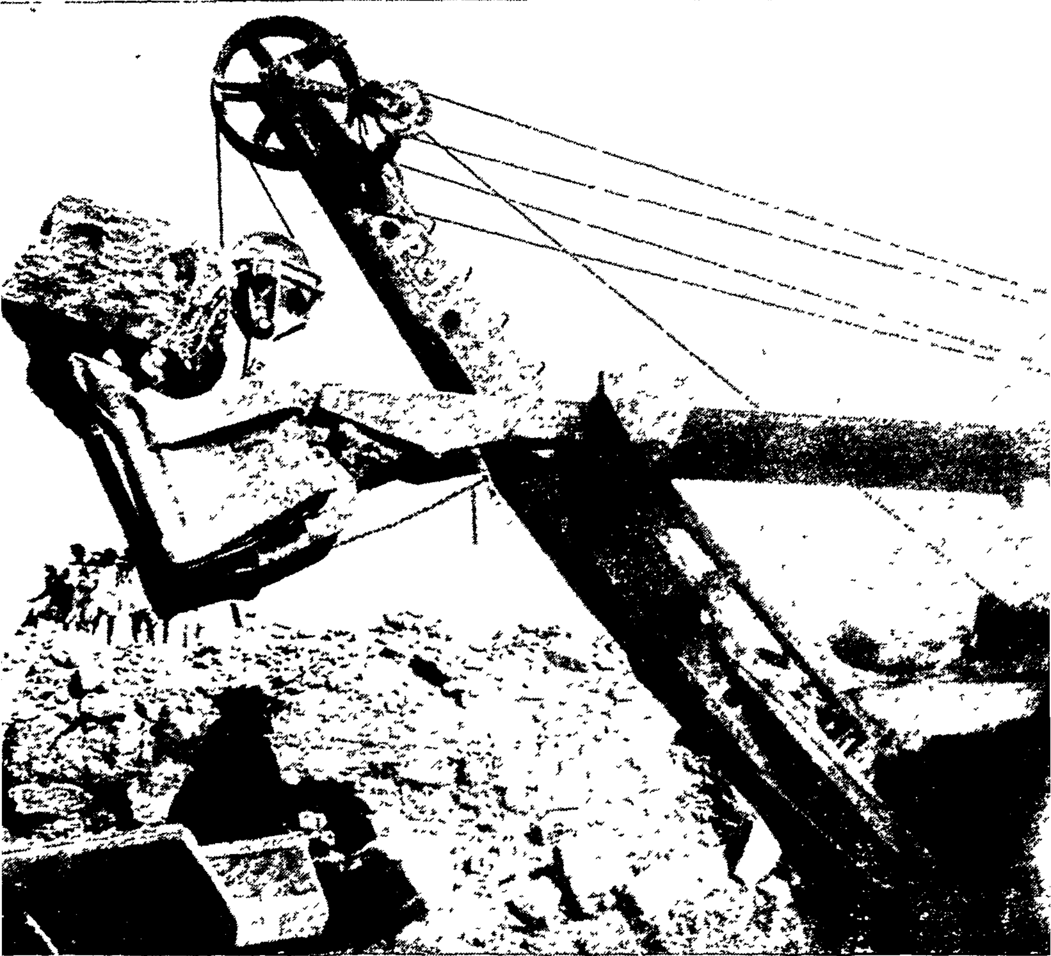
The 91.4 m. level tunnel can be made use of permanently for supplying water to the Krishna delta instead of constructing 18 permanent river sluices in the spillway with the centre line at el. 129.5 m. With this view, it was proposed to construct another horse-shoe inclined tunnel of 8 23 m. dia, with invert el. 121.90 m. and connected with a goose neck to 91.4 m. level tunnel. The total length of this connecting tunnel would be 96 m. The inclined tunnel would be in quartzite and lined to the finished diameter of 8.23 m.

The 121.90 m. level tunnel also has an intake structure in front with two vents of 3.048 m. × 7.62 m. against the head of 61 m. After the lower tunnel was plugged the gates from 91.4 level tunnel were proposed to be refixed for the 121.9 m. level tunnel. There would be a leading channel 9 m. wide with side slopes 1/4 to 1 on the upstream side for both the 91.4 and 121.9 m. level tunnels. An exit channel 90 m. long of about 12.19 m. width and 1/4 to 1 slopes would discharge into the river. The 91.4 m. level tunnel would thus function not only as a diversion tunnel but also for supplying water to the Krishna delta.

The above proposals were placed before a meeting of the Control Board held on April 11, 1963 at the dam site and it was agreed that tenders might be called for, pending examination of the proposals by the Central Water and Power Commission.

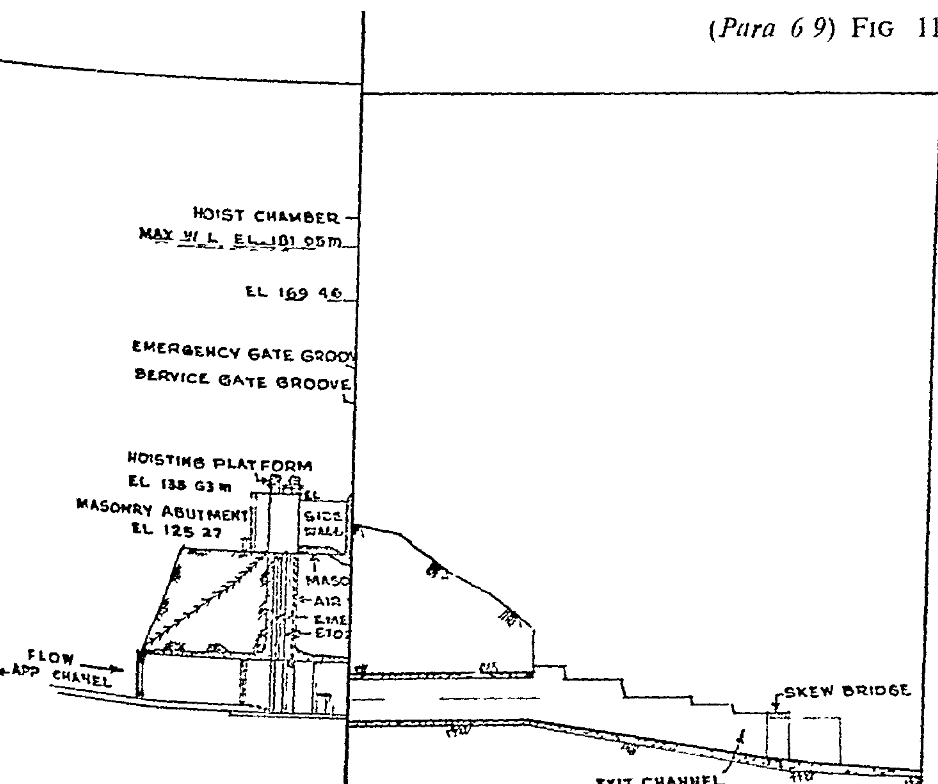
Accordingly, the above proposals were discussed with the Chairman of the Central Water and Power Commission, by the Chief Engineer during his visit to Delhi on April 17, 1963. While agreeing with the proposals, the Chairman suggested that the performance of the inclined tunnel under 44.5 m. head could involve problems of erosion at the junction and that, therefore, it was not desirable to depend on the preformance of the tunnel entirely for supply of water to the Krishna delta for all times to come. He, therefore, suggested that a few river sluices, say eight, in addition to the arrangements of the tunnel as proposed be provided in the dam at el. 129 5 m which could let down flows in case there was any difficulty in the operation of the tunnel.

The main reason for the omission of the river sluices in the earlier proposal was that the work would get hampered. It was felt on



Lifting heavy stones by shovel, carrying by dumpers and unloading for closure of the earth coffer-dam—(*Para* 6 4)

(*Para* 6 9) FIG 11



further examination that provision of even eight river sluices in the spillway as suggested by the Chairman of the Central Water and Power Commission would make it difficult to raise the spillway to the required level during the year. The proposal of providing eight river sluices was discussed with Dr. K. L Rao. He suggested that instead of eight river sluices, two sluices of 3.048 × 7.62 m with the sill at a level of 136.56 m. be provided one on either end of the spillway in the non-overflow blocks and the discharge from the sluices let down into the river through a chute. These sluices would be capable of discharging about 311 cumecs each under the minimum water level of 155 45 m. As these chutes are in the non-overflow portion of the dam, they would not interrupt the progress of the spillway. The cost of the two sluices, including the main and emergency gates and the hoist, was estimated at about Rupees four million as against the Rs. 5 6 million required for constructing eight river sluices in the spillway with the centre line at level 129.5 m. Therefore, the above proposals were implemented. The diversion-cum-irrigation tunnel was commissioned in June 1965 and the construction sluices were plugged in May, 1965.

Diversion Tunnel

6 9 The final proposal for the diversion of the river during construction was through the tunnel. The tunnel was also to regulate the supplies to the Krishna delta. The tunnel was a 8.23 m. dia. horse-shoe shaped structure with two entrances, one with the sill level at 91.4 m. and the other at 121 9 m. level with two intakes connected with a goose neck shaped bore. The 121.9 m. level tunnel was provided with two sets of gates ; one for the control of the operation and the other to serve as an emergency gate. Both the main and the emergency gates were provided with two gates each of 3 05 m. × 8.53 m. The two emergency gates were utilised for the 91.4 m. level tunnel for controlling the water flows during the construction period. These two emergency gates, after serving the purpose to regulate the flows for irrigation, were also proposed for the plugging of the 91.4 m elevation tunnel After plugging the tunnel, the gates and hoists of the 91.4 m. elevation tunnel were contemplated to be removed and utilised as emergency gates for the 121 9 elevation tunnel. Accordingly, the emergency gates and hoists were installed and commissioned at the entrance of the 91.4 m. level tunnel on February 1, 1966 in the tunnel grooves. The face of the 121.9 m. level tunnel control tower is about 22.86 m. downstream of the emergency gate slot of 91 4 m. level tunnel. A 1.52 m. thick wall was constructed joining the side wing wall at 121.9 level upstream of the 91.4 m. level tunnel gate grooves, to prevent any muck rolling down into the gate grooves and jamming the gates.

In the past, gates were lifted off the grooves and removed successfully up to the reservoir level of 121.62 m. The gates were operated in partial opening when the water level was 124 m.

In May, 1966 the M.A.N. emergency gates were closed and work started on the first phase of tunnel plugging. However, due to unexpected floods in the river, this work had to be abandoned and to deplete the reservoir both the gates had to be raised. As the first crop season had started, the discharge had to be passed through the 91.4 m. level tunnel by regulating the gates in June and July, 1966. It was programmed to lower the gates when the reservoir level reached 125 m. or above, depending upon the flow so that the period of suspension of water supply to the Krishna delta might be reduced to the minimum. Accordingly, when the water level rose to 125.8 m. on July 24 1966, attempts were made to close the gates But these efforts proved unsuccessful. As the water level in the reservoir was rising fast, further attempts had to be abandoned. The electrical motors and hoists were installed on a platform at 137.16 m level for the operation of the 91.4 m. level gates As this was under the submergence level, the electrical equipments of the hoist were removed, leaving gear boxes and hoist drums in position. These were allowed to be submerged to be reclaimed when the water level dropped. An uncontrolled flow of 1,020 cumecs passed through the tunnel under a head of 60.96 m. when the water level in the reservoir reached a maximum level of 154.84 m throughout the monsoon season of 1966, though the tunnel was designed for a maximum discharge of 566 cumecs. The situation was fraught with risk. The formation of stray vortices near the intake structure and the occurrence of peculiar deafening noise caused concern to the engineers. Any damage to the intake structure of the tunnel would have entailed loss of control over the river and a consequent adverse effect on the construction of the dam. Remedial measures to close the tunnel would have entailed enormous difficulties at high cost.

Non-closure of Tunnel Gates

6.10 The problem was entrusted to the laboratories in Poona, Hyderabad and in West Germany by the M.A.N. Co., the manufacturers and suppliers of the gates The following were considered the probable causes requiring thorough investigations :

(i) The gate could be underweight.

(ii) The embedded parts, especially the top seal frame, would have been pulled out due to the vertical flow through the gate shafts, preventing the downward travel of the gates.

(iii) Hydraulic phenomena.

The first point was ruled out as the gate was designed for operation up to 45.7 m The second point also had to be ruled out as both the gates were freely moving above 100 m. elevation which is the top level of the tunnel aperture.

As for the third point, all the experiments conducted in the laboratories in Hyderabad, Poona and West Germany arrived at the same conclusion. The failure was attributed to hydraulic phenomena arising out of the vertical flow of water through gate-shafts due to which static head was developed behind the gate when the bottom of the gate approximately approached the top seal channel level of 100 m At this position the gap between the gate and the embedded points was reduced to 17 mm against about 0.33 m. to 0 91 m. above the top seal. The gap between the skin plate and the upstream wall of the gate slot is 0 49 m. Thus due to the constriction on the downstream of the gate, free flow of water was prevented on the downstream side of the gate, resulting in development of a static head though the upstream side of the water had sufficient gap to flow freely. Thus, with the water level at 125 m, there was a resultant horizontal force of 210 tonnes, acting from behind the gate which had the effect of pressing the gate against the upstream wall of gate slot. This jammed the counter guide rollers fitted to the gate on the upstream side, thus creating sliding friction instead of rolling friction.

Reclamation Work

The reclamation work was resumed only when the reservoir emptied below the girders supporting the hoist so that the electrical equipment could be installed and an operation platform could be available i.e., at the level of 132 59 m At the same time, the most important issue was to conserve the reservoir water for feeding the crops

The first requisite for the successful reclamation of the gate was to stop the vertical flow through the gate slots without endangering the gates or hoist ropes or allowing any foreign material to enter the gate grooves in conducting such an operation. One proposal was to isolate the gate slots, by lowering with the aid of floating punt, fabricated steel cribs lined on sides with steel plates to form a cellular coffer dam round the gate slots But the presence of strong whirls in front of the tunnel gate and above the gate slots ruled out this proposal Therefore, the operation had to be delayed until the water level lowered to 123.4 m. level.

The following sequence of operations was planned .

(i) Hooking the gates at suitable points by suitable wire ropes.

(ii) Changing the hoist wire ropes where necessary.

(iii) Removing debris, floating matter, stones wedging the gate in grooves utilising services of divers.

(iv) Lifting up the gate off the grooves for inspection.

(v) Repairs or replacing counter guide and lateral guide rollers.

(vi) Finally to operate gates.

As the operation started, Mr. M. Rangiah, Assistant Engineer, with his staff, got down to 121.9 level to commence work behind the 105 m. high wall connecting wing walls of 121.9 m level tunnel described already in para 6 9. This tiny wall withstood the rising flood ; but at the falling flood when the tail water level completely receded, it could not withstand pressure of water only on the upstream side and gave way This caused a sudden gush of water creating a vertical flow through the 91.4 m. tunnel gate slots. Out of the 12 persons who were working behind the 1.5 m. high wall, six were sucked into the gate slots and were killed. They were Mr. Rangiah, Assistant Engineer, M. Ratnakar Rao, Junior Engineer, Mr. Sambasia Rao, Section Officer, Mr Sankaranarayan, Maistry, Mr. Ahmad Kully, Mola Syrang and Mr. Krishnamurthy agent of Messrs. Escorts Ltd., the contractors for supply of the gates.

All repair works to the gates were carried out round the clock and the jammed gates had to be repaired at 18.2 m. below the approach platform in the gate slot well, where very limited space was available, and where one could hardly move. The repairs were completed by February 3, 1967. All the operations were completed in 108 hours. The water level in the reservoir at the end of the operation was 119.33 m. This assured continuous supplies of water to the 0.137 million hectares second crop in the Krishna delta.

This difficult work could be achieved due to the zealous and sustained efforts of duty conscious officers. Mr. G.V. Narasimham, Executive Engineer and Mr. G. K. Reddy, Superintending Engineer played a prominent role under the guidance of Mr. A. P. Ranganatha Swamy, Chief Engineer.

The right side gate could not be fully closed. When the supplies through the tunnel were stopped in April 1967 there was a chance to examine the reasons for the partial non-closure of this gate. On lifting the gate fully from the grooves it was noticed that the left side rubber seal was damaged, indicating a pointed material obstruction. It was felt that by replacing the missing lateral guide roller the gate could be pushed to a side, by clearing the obstruction. No sooner was this done, than the gate could go down fully. Thus ended an episode which had become a nightmare and gravely threatened the safety of a very complicated and important structure.

The condition of an abnormal and heavy horizontal thrust on the downstream face of the gates, in the opposite direction of the design criteria, pressing heavily against the counter guide rollers, was experienced for the first time in gate history It was a peculiar phenomenon that could not be anticipated.

Plugging of 91 4 *m. Level Tunnel and Operation of* 137.2 *m Level Chute Sluices*

6.11 The work on the tunnel, which was taken up in March 1963 was completed by June 1965 and the tunnel commissioned. During the period of construction of tunnel, the work progressed unhampered. The progress of work in the spillway blocks was as follows :—

Sl. No.	Period	Lowest level of spillway block
1.	June 1963	71.93 m.
2.	June 1964	106 68 m.
3.	June 1965	124.97 m.
4.	June 1966	155.45 m.

By December 1965, eighty-five per cent of the work on the dam was completed. This made it possible to let out water into the canals in June 1966.

When the dam rose to a sufficient height over 137.2 level, the 91 4 elevation tunnel was plugged with concrete The emergency gates of 121.9 elevation tunnel were permanently used for the closure of the 91.4 elevation tunnel. Plugging of the 91.4 m. level tunnel posed a problem in view of the fact that water was to be let out for irrigational purposes in Krishna delta from about November to April and June to July through the diversion tunnel. So the work was carried out in phases and plugging had to be resorted to in stages The work was carried out so that the Krishna delta ayacut did not suffer for want of supplies through the tunnel.

The 91.4 m. level tunnel emergency gates were lowered on April 27, 1967 Preliminary works such as formation of ramp, excavation of shear keys and dewatering them were completed by May 5, 1967. Partial plugging leaving an area of 18 60 sq m in the roof portion was started on May 6, 1967 and completed by May 31, 1967 by laying 2264 cu. m. of concrete. The gates were raised on June 7, 1967 and water

was let out to restore supplies to the Krishna delta. When there was a sudden rise of water level on July 5, 1967 and further freshes were expected, the gates were lowered The tunnel barrel was plugged to about 18 29 m. length by placing second stage concrete by July 10, 1967 and water was let down through the 121.9 m. level tunnel on July 11, 1967 after-noon The mix used for the plug was 210 kg per sq. cm. strength concrete. To cope with the small leakage a G.I. pipe of 254 mm. dia of adequate length with valves was embedded in the plug concrete. This pipe was subsequently plugged. Grout condulets were provided to grout the plug concrete for all-round tightness etc. Subsequently during the floodseason when flood was overflowing the spillway, the 91.4 level tunnel barrel was plugged completely, thus ending the diversion problems of the mighty river.

Two chute sluices of 3.048 m. × 7.62 m. with the sill level at 136.56 m. were constructed in the non-overflow blocks 25 and 51 to supply water to the Krishna delta in case of need. Thus the 121.9 m. level tunnel served as an alternative arrangement to ensure secured supplies to the delta, and for the regulation of river flows for irrigation in the delta. The 121.9 level tunnel would also serve under emergency when the reservoir level is depleted abnormally or the chute sluices go under repairs.

At the final closure, due to plugging of the 91 4 m. level tunnel the 121.9 m. level tunnel served until the water level rose to 140.21 m. when the chute sluices were operated. This marked the end of the diversion of the flows during construction.

Control of River after Dam Construction

6 12 To harness the waters for irrigation and development of power, outlet of water from the reservoir is regulated by high head hyraulic steel gates or by low head steel gates. The various control arrangements are discussed in the following paragraphs :

(i) *Diversion tunnel :* The bed level of the river is at 73.15 level and the first take off from the bottom of the dam is the diversion tunnel. The tunnel is a diversion-cum-irrigation tunnel and consists of a horse-shoe shaped tunnel described above. The 121.9 m level goose-neck tunnel is controlled by two emergency gates of size 3 05 × 8 23 m and two main gates of size 3 05 m. × 7.62 m. Ultimately the elevation 91 4 tunnel was plugged to a length of 91 m in front of the junction of the goose-neck tunnel. The 121 9 m. level tunnel is the outlet of the waters of the river Krishna from the reservoir to the river course downstream of the dam.

(ii) *Penstocks :* Another outlet from the reservoir into the river is through penstock pipes feeding the turbines while generating power.

There are eight penstock openings 5 56 m in dia. located one each in blocks 16 to 23 of the dam The centre line of the penstocks is at 123.44 m. level. Embeded parts have been installed for all the eight vents, but emergency gates have been provided only for two The fabrication of penstocks was undertaken by the Government workshops at Seethanagaram, Vijayawada. The penstock gate has a stop log groove in front and a trash rack in front of the stop log grooves

(iii) *Chute Sluices* The next higher off-take from the reservoir into the river course is through the two chute sluices located in the non-overflow blocks 25 and 51 with the sills at 136 56 m level. There is one emergency gate proposed to be operated by a 125 tonne gantry crane and one main gate for each chute sluices

(iv) *Right Penstocks* These comprise of three vents 4.57 × 13 71 m discharging water from the reservoir into the Nagarjunasagar right canal and in so doing arrangements were contemplated to generate seasonal power. As the power scheme was not finalised, embeded parts for emergency and bulk head grooves were installed. The sills of the penstocks are at 146.1 m level and are located in blocks 71 and 72.

(v) *Right Canal Regulator*. This comprises of nine vents of size 3 05 × 4.57 m located in blocks 73, 74 and 75 discharging water into the right canal The sill of the vents is el 149 00 m There is one emergency gate operated by a Gantry crane to serve all the nine vents and nine main gates.

(vi) *Left Canal Regulator*. This comprises of three vents 3 05 × 7.62 m. and is located in a saddle on the left flank with the sill at el. 149 00 m There is one emergency gate operated by a 75 tonne capacity Gantry crane for all the three vents and three main gates.

(vii) *Crest Gates* These are low head gates twenty-six in number. The size of the gates is 13 716 m. × 13.11 m. and are of radial type with sill at 166 42 m level

(viii) *Construction of the High Head Gates and Other Components:* All the high head gates installed in the Nagarjunasagar dam are similar in construction The gates for the diversion tunnel, penstocks, chutes and left canal regular gates have been manufactured and supplied by Messrs M.A N, Germany. The gates for the right canal regulator have been supplied by Messrs. Tungabhadra Steel Products Limited, India, Tungabhadra.

Steel Gates

6 13 For effective control of diversion works, special expertise is required in the design, manufacture and erection of steel gates. Hence, the gates as used in Nagarjunasagar, have been described in detail in this chapter.

The component units of hydraulic steel gates are:

(i) gate leaf,
(ii) hoist and
(iii) embedded parts.

Gate leaf

6.14 The types of gates installed are fixed wheel gates. The gate leaf is divided in Sections in 4 mm. horizontal planes so that it is easy to transport and erect it. It was stipulated that no single piece of equipment should weigh more than eight tonnes, and so the gate was manufactured in pieces. Another advantage achieved by such sectionalisation is flexibility. Each piece has two rollers on either side and so will be always in contact with the roller track. The pieces of gates are joined by the steel strap plates bolted with tight-fit bolts. To prevent leakage a jute cloth is placed underneath the strap plate and nylon washers provided for bolts. The strap is skilfully manipulated and merged into the water seals provided round the gate, thus making the gate water tight. The gate assembled in pieces, though joined by strap pieces has a little flexibility. This flexibility facilitates all the rollers taking an equal load in spite of any misalignment in roller tracks, as each piece of gate is independent having only two rollers on either side.

The gate leaf comprises of (i) skin plate and backing girder, (ii) end rollers and axles, (iii) seals, (iv) guides, (v) bottom pulleys, and (vi) filler valve (in the case of emergency gates only).

Skin Plate and Backing Girders

(i) The skin plate and backing girders are welded constructions and the end boxes being formed to house the rollers. The gate frames are stress relieved.

Rollers and Axles

(ii) The axles are of stainless steel; needle type bearings are used for gates, supplied by Messrs M A. N. Timken tapered rollers are used for gates supplied by Messrs. Tungabhadra Steel Products Limited. The rollers of the gates supplied by M.A N. are of special steel and are non-flanged, having a spherical tread. The rollers for the gates supplied by Messrs. Tungabhadra Steel Products Ltd.,

(T S P) India are of cast steel, cylindrical in shape and are of the side flange type and mounted on eccentric axles so that they can be adjusted. Lubricating arrangements are provided for the bearings.

Seals

(iii) The seals provided are of three types The side seal is a 'Musical note' type, the top seal a double stem type and the bottom seal a flat type. The seals are slightly precompressed when the gate is in position The sealing effect increases with the water head.

The seals are placed in front or rear of the gate. In Nagarjunasagar project, seals are placed in front of the main gate and in the rear for emergency gate

Guides

(iv) The guides are lateral and counter types. The laterals are located on the side of the gates and the counter on the side opposite to the roller track. The guides are to facilitate the movement of the gate in the grooves. Messrs M A N. have provided spring loaded roller guides, the springs comprising of Bellville washers Messrs. Tungabhadra Steel Products (T.S.P.) have provided a fork type guide shoe for lateral guide and a curved block for counter guide. For the emergency gates of chute and right canal regulator gates, the side guide is provided.

Bottom Pulleys

(v) The distance of the centre of gravity of the gate from the skin plate is determined and the hoist pulleys are fixed at the top of the gate. For the M A N Gates single point suspension and for the T.S.P. Plates two point suspension are used

Filler Valve

(vi) All emergency gates are to be lifted under balanced water pressure conditions, though occasionally they can be used under unbalanced conditions also When lifting, the emergency gate is subjected to water thrust, from a closed position, the main gate is to be lowered to sill and the space between the main gate and emergency gate is exposed to the reservoir through filler valve or through a bypass arrangement.

The filler valve stem is attached to the hoist bottom pulley. When the hoist is operated, the rope becomes taut lifting the filler valve. Water rushes from the reservoir through the filler valve to the rear of the emergency gate After allowing sufficient time to fill up the space in between the main and emergency gates, the emergency gate is lifted under balanced conditions.

9

The shape of the bottom piece of the gate is so formed that no turbulance is created while discharging the water. For the main gate the bottom of the gate is slightly inclined to the horizontal so that the jet clears the gate edge smoothly. For the emergency gate a curve is given at the bottom.

Hoists

6 15 Except for the penstock gates where hydraulic hoists are provided all the other gates have rope hoists.

Rope hoists supplied by M.A.N. consist of a foundation frame, an electric motor, an electromagnetic brake, a worm reduction gear box and a further reduction for powering the hoist drum. The hoist drum is a two-way winding drum. This is for single point suspension. The hoist of T.S P. comprises of a central drive unit comprising of a motor, an electromagnetic brake and a worm reduction. The power is transmitted to the end drive unit comprising further reductions and hoist drum. This is for two-point suspension. In both types of hoist two independent ropes are used for suspending the gate. A continuous rope could be used, but this is avoided because should one rope snap, the gate falls to the bottom; whereas if two independent ropes are used, the second one can still hold the gate in position. The rate of lift of gate is about 0.6 m. per minute.

Dial indicators and electric limit switches are provided for the operation of the gate. Dial indicators are geared to the main drive unit. Limit switches accentuated by a gear train from main unit are incorporated for safety.

As stated earlier, the penstock gate is provided with a hydraulic hoist. This facilitates varying rates of opening and closing the gate, depending on the emergency. The hydraulic hoist permits closure of gate within 20 seconds so that minimum damage occurs to the power station behind, should there be any bursting of the pressure pipes. However, the principle employed in this gate is that the gate will close down by its own weight and the hydraulic hoist facilitates lifting the gate ensuring varying rates of regulation.

The gate is attached to the hydraulic hoist stem by links, the individual lengths of which correspond to the vent opening If the gate is to be lowered, or the gate is to be 'dogged' for attaching or detaching the links, the above hoists have certain safety devices operated electrically through limit switches. The switch for lowering becomes inoperative when the gate touches the bottom-most position. Similarly, there is an automatic cut off when the gate is in the full vent open position. The gate is always to be kept in the open position unless required

to close. This being a hydraulic hoist, there is the possibility of leakage of oil which results in lowering the gate. If the gate drops down 500 mm. the motor automatically starts and pumps oil lifting the gate to the fully lifted position and the motor is cut off. In case the leakage is so heavy that the pump is unable to lift the gate, a buzzer automatically blows, giving a warning. There is provision for remote control of the hoist from the power houses. The hoisting of emergency gates of chutes, bulk head gates and the right canal regulator emergency gates of chutes, is by a gantry crane on the top of the dam. The gates are operated by the Gantry crane through a lifting beam. There are two hooks on the lifting beam which hook the gate automatically and also release it automatically as required.

Embedded Parts

6 16 The embedded parts comprised of:

(i) sill beam,
(ii) seal track
(iii) roller track,
(iv) counter and lateral guides and
(v) lining.

Sill beam

(i) The sill beam is the piece which is embedded in the concrete to form the sill on which the bottom seal of the gate rests It comprises a full or a half of 'I' section. The seal seat is a colclad stainless steel plate welded on to the 'I' section.

Seal Track

(ii) The seal track is the track on which the side seal moves. This comprises of a mild steel 'T' section, on top of which a colclad plate is welded. The seal track can be mild steel but the colclad plate (stainless steel coating over mild steel flat) is used for its rust proofness

The top seal seat is similar to the side seal seat in construction but is in a horizontal position and rests on the seat when the gate is in a closed position.

The slide plate is provided for the main gates only on the rear face at the breast wall. On this moves the top seal when the gate is lifted This prevents water from rushing over the gate In addition, the gate is held firmly so that vibrations are minimised. The slide plate is also a colclad plate

Roller Track

(iii) The roller track is the track on which the roller moves. This takes the entire load coming on the gate and transmits it to the counters. The track comprises of a stainless steel flat of sufficient thickness and width, bolted on to a backing mild steel section, embedded in concrete. The bolting is by 'Allen' screws, in the case of gates supplied by MAN. In the case of gates supplied by T.S.P a stepped roller track is provided and the bolting is by counter sunk bolts. The track flat is made separate from the girder to facilitate replacement when it wears out

The seal track, the roller track and the slide plate are installed to a height slightly more than twice the height of the gate from the sill. Above this height only light sections are embeded in line with the roller track, lateral and counter guide rails to guide the gate in the groove and on to the roller track.

Counter and Lateral Guides

(iv) These are light embedded sections on which move the guide rollers or shoes fitted on the gate. Steel lining is provided round the conduit behind the gate grooves to a length of about 1.2 to 1.8 m. so that high velocities of water do not damage the concrete. The liner plate is a 12 mm. thick M S plate anchored into concrete firmly at close intervals to avoid flexure, should water pressure develop behind the liner plate owing to leakage. The embedded parts in the groove are an integral part of the lining provided in the groove.

Emergency gates of chutes and the right canal regulator are on the face of the dam. The roller track, seal track, liner plate and guide track have all been provided in one piece.

Shafts

6 17 The shafts are of a great height Facilities are provided for personnel to go down the shaft to inspect the gate while in operation and also to inspect and repair it if required, by lifting the gate. An inspection chamber is provided above the maximum water level so that the gate can be serviced or repaired.

Erection Procedure

6.18 For erecting the embedded parts, accuracy is required. The tolerance in erection is limited to 1/2 mm. It was not advisable to erect the embedded parts in primary concrete as there were no hold fasts for keeping the parts in position firmly during concreting It was necessary to leave block-outs in primary concrete with a liberal number

of anchor plates so that the embedded parts could be erected to required accuracy.

Secondly, the concreting was done carefully. As the gates are stress relieved, gas or arc welding was avoided.

The Radial Crest Gates for Nagarjunasagar Dam

6 19 These are the low head gates installed on the crest. The work of fabrication and erection was entrusted to Messrs. Jessop and Co., Ltd , Calcutta.

Twenty-six radial gates of size 13 716 m × 13.420 m. are provided for the spillway of the Dam The radial gate consists of a skin plate which spans continuously and is supported by vertical stiffeners welded to the skin plate. Three horizontal girders of welded built up sections are provided to support the vertical stiffeners and the horizontal girders are supported by inclined end arms. Suitable bracings are provided between the horizontal girders. The end frames pivot on trunnion bearings mounted on the anchorages, embedded in the concrete piers. The inclined gate arm struts of the end frames transfer the loads through bearings to the anchorages. The horizontal force resulting from the inclination of the end frame at the trunnion from the side is taken up by the tie bar which connects the trunnion ends of the end frame

The skin plate has five vertical splices to facilitate easy transportation and erection Vertical splices are rivetted at site with sealing welds to prevent leakage Four side rollers, two on each side of the gate, are provided to minimise the lateral movement during operation. Side and bottom rubber seals are provided to prevent leakage of water past the gate. The trunnions are fitted with self-aligning roller bearings. Spherical tread roller bearings were used.

Each gate is equipped with a separate motor driven hoist. The hoist is electrically operated and also mechanically, consisting of a drive unit and a two hoist drum assembly unit The entire hoist assembly is located on the hoist bridge over the piers on the downstream side of the spillway road bridge.

Design Consideration

6 20 (*a*) Normal condition · Maximum water level upto the top of gate 179 832 m (*b*) Over toppling condition : maximum water level upto 181 03 m have been taken into account.

For the design of the gate leaf, the dead load is neglected, its effect being negligibly small. However, the dead load is taken into account for the design of the end frames. The skin plate is considered continuous

in the horizontal direction as it is supported by the vertical stiffeners. A thickness of 1.6 mm. is allowed for corrosion of the skin plate.

The vertical stiffeners are designed as continuous supported by the three horizontal main girders. The horizontal girders are bolted to the vertical stiffeners and they are designed as simply supported by the arm struts of the end frames which overhang on each side.

Design of Anchorages

6.21 The anchorage is designed for the pond water level condition of 179.83 m. and permissible stresses are increased by 33⅓% for the maximum reservoir level.

The anchorage is designed for (1) one gate fully open and the adjacent one fully closed, and (2) both gates fully closed.

A problem in regard to procurement of spherical roller bearings was encountered. The bearings had to be imported. They are of S.K.F. make.

Salient Features of Gates

6.22 The salient features of the various gates erected in the dam, are given in the appended statement. (Table 6.1)

6.23 The following are unit costs of gates obtained in Nagarjunasagar dam based on tenders :

(*A*) Unit Rate (Cost per tonne) obtained in Nagarjunasagar dam.

Serial Number and Description.	Diversion Tunnel Gates.	Right Canal Regulator Gates.	Left Bank Penstock Gates.	Radial Crest Gates
	Rs.	Rs.	Rs.	Rs.
I. MANUFACTURE AND SUPPLY				
(1) *Embedded Parts*				
(*a*) Manufacture and supply including transportation to dam site.	4,654	10,261	7,796	22,600
(*b*) Erection at dam site .	4,419	3,512	3,733	6,474
(2) *Gates*				
(*a*) Manufacture and supply including transportation to the dam site.	4,844	6,920	4,730	3,410
(*b*) Erection at site ..	4,419	3,512	3,733	241
(3) *Hoisting Equipment*				
(*a*) Manufacture, supply including transportation to site	5,693	5,309	3,310	3,410
(*b*) Erection at dam site ..	4,419	3,512	3,733	241
II COST OF FABRICATED MATERIAL INCLUDINC TRANSPORTATION AND ERECTION.	6,094	5,859	5,289	3,915

(*B*) Unit Rate (Cost per sq m) obtained in Nagarjunasagar Dam.

Serial Number and Description.	Diversion Tunnel Gates.	Right Canal Regulator Gates.	Left Bank Penstock Gates.	Radial Crest Gates
	Rs.	Rs.	Rs.	Rs
I. MANUFACTURE AND SUPPLY				
(1) *Embedded Parts*				
(*a*) Manufacture and supply including transportation to site	3,372	5,602	12,271	620
(*b*) Erection at site ..	3,873	1,922	5,892	183
(2) *Gates*				
(*a*) Manufacture and Supply including transportation to site.	4,247	3,780	7,022	2,433
(*b*) Erection at site ..	3,873	1,922	5,892	545
(3) *Hoisting Equipment*				
(*a*) Manufacture, and Supply including transportation.	4,994	2,883	1,741	2,433
(*b*) Erection at site ..	3,873	1,922	5,892	545
II. COST OF FABRICATED MATERIAL INCLUDING TRANSPORTATION AND ERECTION AT SITE.	15,942	13,338	28,096	3,780

6.24 The gates were erected by M/s. Jessop & Co. Ltd. Calcutta in three seasons with S. K. F. spherical roller bearings. This work was accomplished with precision under the guidance of Sri S. K. Mukherjee, Engineer of the firm.

The anchorage on pier 30 for the radial gate and air face view of six of the radial gates, are shown in photos at page 136.

RESUME

6 25 In the diversion of big river flows during construction and their control after building dams, special expertise is required for the design, manufacture and erection of the gates. Any delay in planning the gates will upset the programmes. Consequent to non-settlement of the dispute on the sharing of the Krishna water among the states, the crest gates were delayed for two years. Project Administrators have to be vigilant so that the gates could be procured and erected in time,

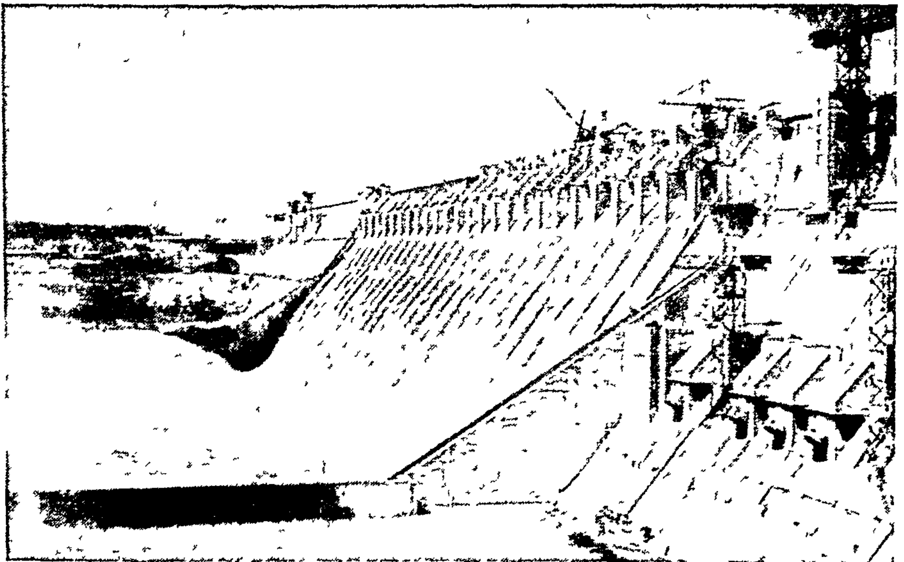
TABLE 6.1

(a) Salient Features of Gates in the Dam

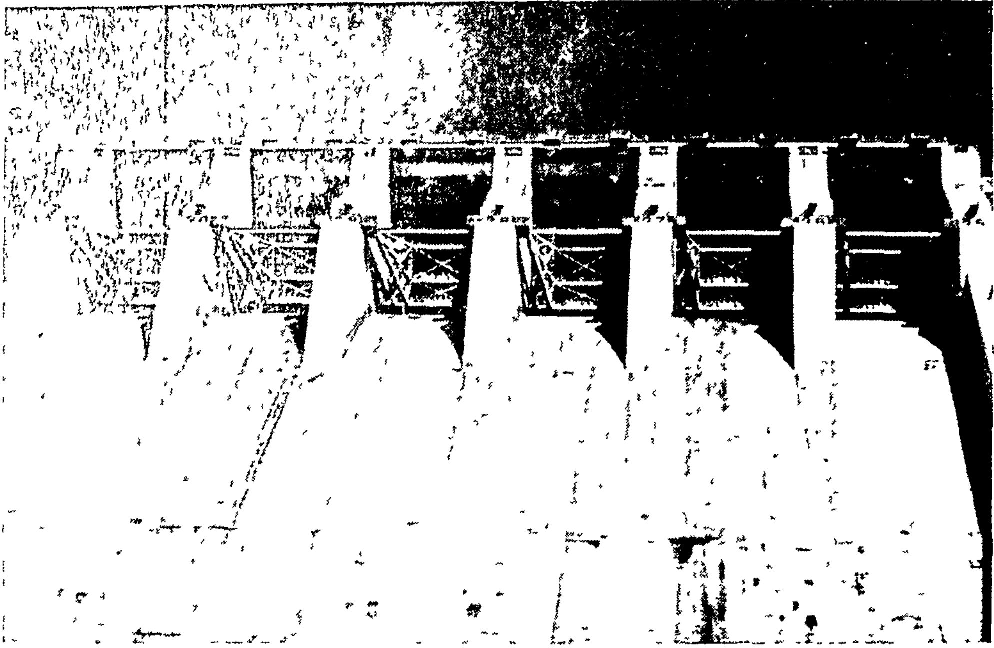
S No	Particulars of gates.	Unit	Diversion Tunnel		Chute sluice gates in blocks 25 & 51		Right Canal Regulator Gates		Left Bank Penstock gates
			Emergency gate	Main gate	Main gate	Emergency gate	Main gate	Emergency gate	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	Sill level	m	121.92	121 92	137.16	.	149.05	149 05	123 44 (Central level)
2.	Maximum water level .	m	181.05	181.05	181 05	181.05	181.05	181 05	181 05
3	Operational head for gates .	m	48.77	48 77	35 05	35.05	35 05	35 05	57 61
4	Size of gate (over all) .	m	4 14 × 8.76	4 14× 7 97	4 14 7 97	4 42 × 9 60	3 05 × 4 57	3.657 × 2 743	5 493 × 8 268
5	Hoist capacity .	Tonnes	72	72	46	Gantry crane	30	Gantry crane	49
6.	Thickness of skin plate	mm	30	30	30		25		50
7	Backing girder flanges and webs	mm	200 545	150 650	340 600		210 600	.	200 800
8	Rollers per gate . .	Number	28	24	12	12	12		16
9	Dia of roller .. .	mm.	450	450	500		400		550
10	Width of face of roller	mm.	70	70	80	..	121	..	100
11	Wire rope for hoist .	mm	33	33	25		28 5		No wire rope
12	Number of parts of rope .	Number	2×4	2×4	2×4		2×2		Nil
13	Power of motor driving the hoist	KW	18	18	8		5 7	.	12 5
14	Weight of gate .	Tonnes	35 83+ 7 00 (Ballast)	27 71+ 7.00 (Ballast) 27.00	40	9 00 + 6 00 (Ballast)	19		45
15	Weight of hoist .	Tonnes	15 78	15 59	8 132	Gantry		..	11 21
16	Weight of embedded parts .	Tonnes	15 52	32.43	17 22		15 9	..	14 86
17	Contract amount according the suppliers agreement entered		Rs 19,04,001 including D M 12,03,348		Rs 12,09,798 including D M 8,83,643		Rs 25,80,000		Rs 17,69,550 including D M. 12,05,338



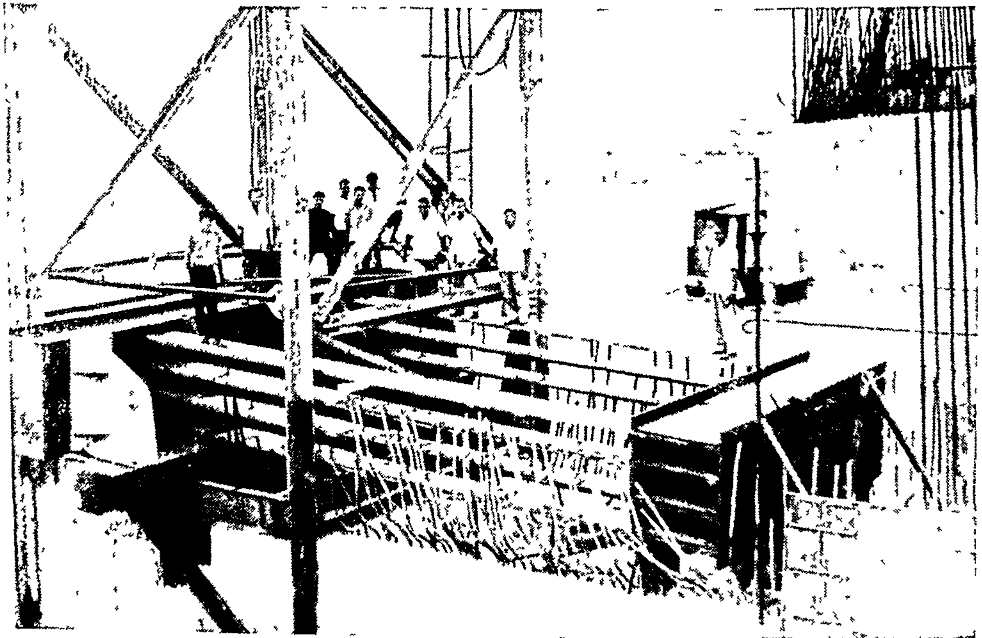
View of Diversion Tunnel—Left Vent Gate in closed position—(*Para* 6 9)



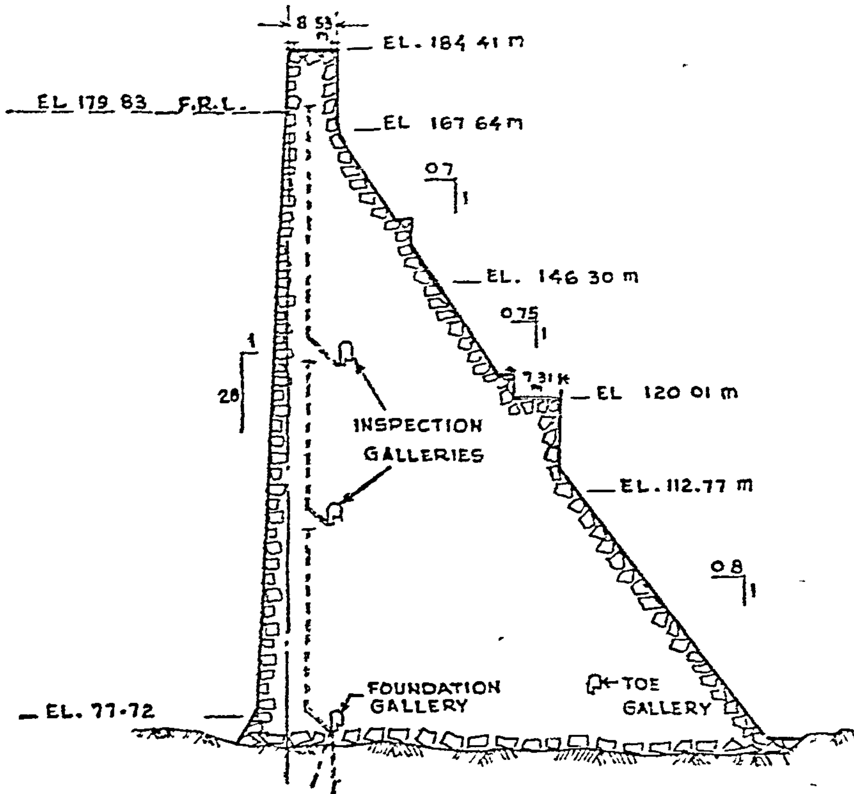
View of the Dam, showing Penstocks, Chute Sluices & Crest Gates—(*Para* 6 12)



View of Airface of six of the Radial Gates—(*Para* 6.19)

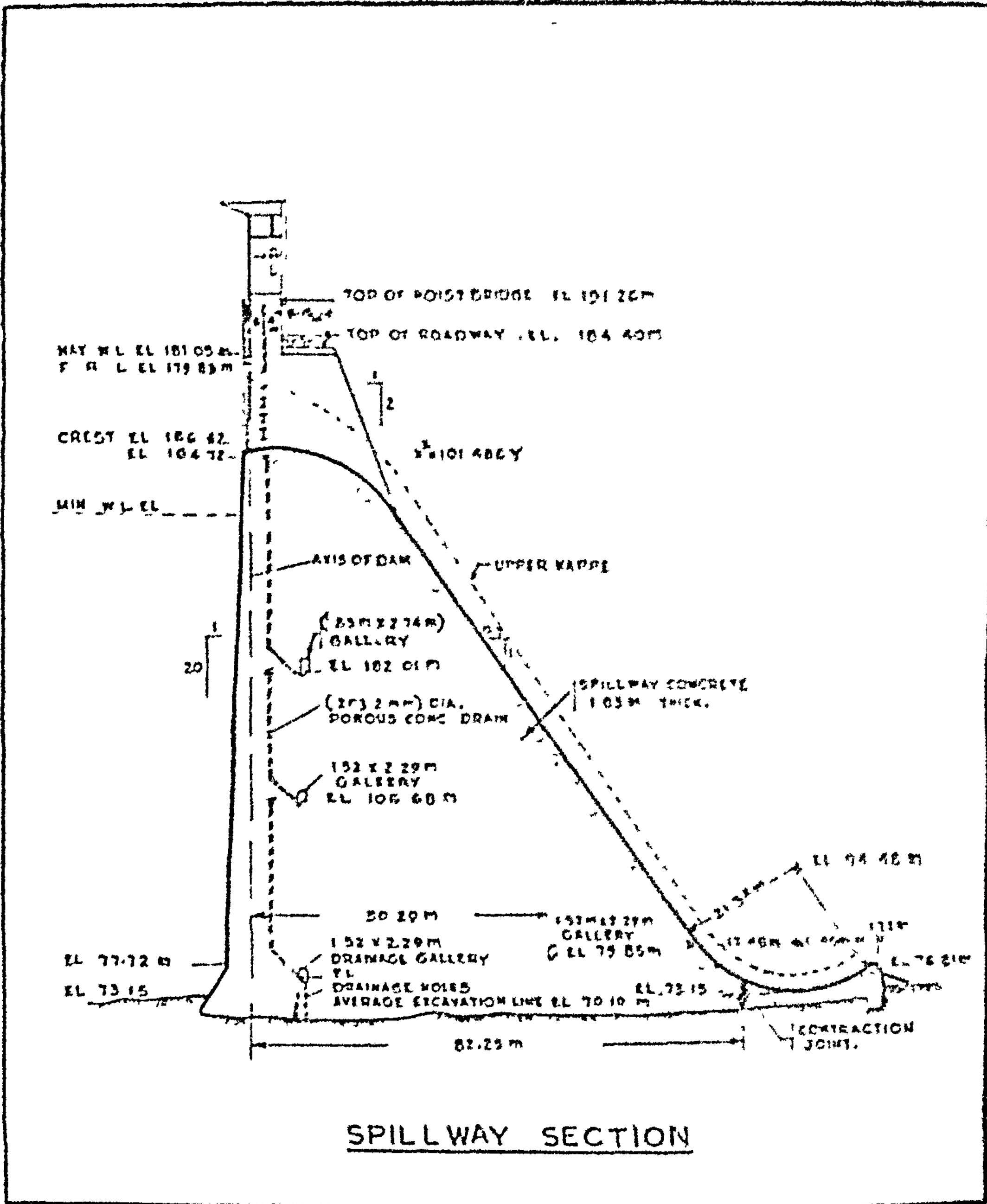


View of the Anchorage on pier 30 for Radial Gates—(*Para* 6.19)

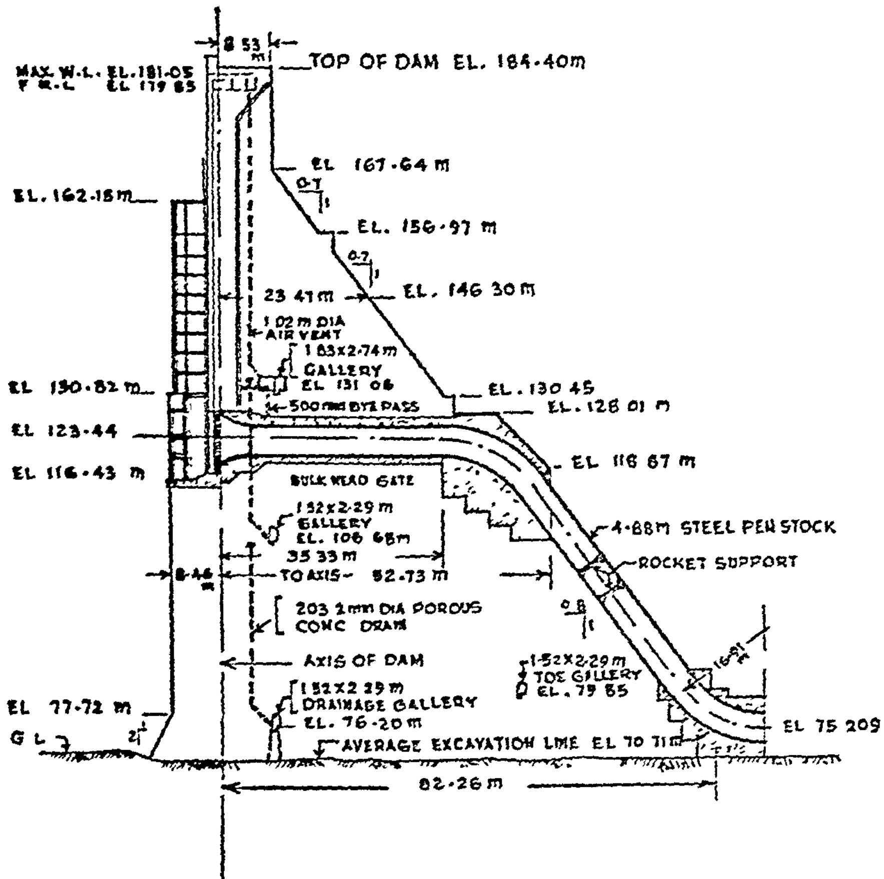


NON-OVER FLOW SECTION

(*Para* 7.2) FIG. 13



SPILLWAY SECTION



POWER DAM SECTION

CHAPTER VII

DESIGN AND INSTRUMENTATION

The Nagarjunasagar dam across the Krishna is 15,956 ft. (4860 m.) long, of which 4,756 ft (1,450 m) is masonry dam in the centre of the gorge flanked by earth dams, the total length of which is 11,200 ft. (3418 m) The masonry dam has a spillway length of 1,545 ft (471 m) flanked by non-overflow sections, 1,397 ft. (426 m) on the left and 1,814 ft, (554 m) on the right Fig 12 to 16 show the cross-sections of the spillway, non-overflow, power dam and earth dam.

7 2 *Salient Features*

The salient features of the dam are as follows :

Masonry dam

1.	Catchment area at dam site	.	83,087 sq miles (215,195 sq km)
2	Average Annual rainfall	..	35 inches (889 mm)
3	Maximum discharge observed at site	..	11 70 lakh cusecs (33,100 cumecs)
4	Maximum Design flood		
	(*a*) As assessed from discharge data	.	15.4 lakh cusecs (43,600 cumecs)
	(*b*) As assessed from extended data	..	19 00 lakh cusecs (53,800 cumecs)
5.	Full reservoir level	.	590 00 ft. (179.95 m.)
6.	Maximum water level	.	594 00 ft for the design flood of 15 4 lakh cusecs or 43,600 cumecs.
7.	Gross storage capacity	..	9 37 m a. ft (11,557 m cum.)
8	Dead storage capacity	..	4 86 m a ft. (5,994 m. cum)
9.	Live storage capacity	..	4 51 m a ft. (5,563 m.cum)
10	Total length	..	4,756 ft (1,450 m.)

11.	Spillway	.. 1,545 ft. (471 m.)
12	Non-overflow including power dam	.. 3,211 ft. (980 m)
13.	Maximum height of the dam	.. 409 ft. (124.5 m.)
14.	Maximum base width	. 320 0 ft. (97.4 m)
15.	Top width	.. 30.50 ft. (9.20m.)
16.	Top of dam	.. 605.0 ft. (184.50 m)
17.	Spillway crest elevation	.. 546.0 ft. (166.5 m.)

Outlets

(*a*) Chute sluices .. 2

Size—10′ × 25′
(3.048 m. × 7.61 m.)
Location—One in block 25 and the other in block 51.
Sill at 450 0 ft. (137.0 m.) Level

(*b*) Penstocks .. 8

Diameter—16 ft. (4.875 m.)
Location—One each in the blocks No. 16 to 23.
at 405.0 ft. (123.2 m.) Level

(*c*) Power sluices .. 3

Size—15′ × 38′ (4.56 m. × 11.58 m.)
Location—in blocks 71 and 72.
at 479.0 ft. (146.0 m.) Level

(*d*) Irrigation sluices ..	Jawahar canal	Lal Bahadur canal
	9	3
Size	10′ × 15′ (3.05 m. × 4.56 m.)	10′ × 25′ (3.05m. × 7.62 m)
Location	Right flank	left flank
Sill Level	489 0 ft. (149.00 m.)	489 00 ft. (149.00 m.)

18. Spillway .. 26 Bays.

Size—45′ × 44′ (13.7 m. × 13.4 m.)
Crest elevation—546.0 ft. (166. 5 m.)
Type of gates—Radial
Spillway pier thickness—15 ft. (4.56 m)

Earth Dams

19. (*a*) Length of left earth dam .. 8,400 ft. (2,559 m)
(*b*) Length of right earth dam .. 2,800 ft (852.5 m)

11,200 ft. (3,411.5 m.)

20.	Maximum height above foundation level	.. 85 ft. (25.9 m.)
21.	Top width	.. 30 ft. (9.14 m.)
22.	Top level	.. 610.0 ft. (186.0 m.)
23.	Type of section	.. Homogenous earthfill.

Provision for Development of Power

24.	(*a*) Left side—8 penstocks 16′ dia (4.875 m)	
	(*b*) Near right canal Head regulator	.. 3 power sluices of 15′ × 38′×(4.56 m. 11.58 m.)
	(*c*) Near left canal Head regulator 2 power sluices of	.. 2 of (10′ × 25′) (3.05 m. × 7. 62 m)

25.	*Particulars of Construction :*	
	(i) Masonry including concrete	.. 7.37 m. cft. (208.500 cu. m.)
	(ii) Earth work excavation	.. 3.00 m. cft. (84,900 cu. m.)
	(iii) Cement	.. 1.10 million tonnes
	(iv) Steel	.. 0.60 million tonnes
	(v) Number of workers employed during peak period of construction	.. 45,000

Maximum Flood Discharge and Spillway Design

7.3 The drainage area of the Krishna at the site is 83,087 sq. miles (215,195 sq km). While designing the dam there were no observed data of discharges at the dam site. Daily discharge data were, however, available from 1894 onwards at Prakasam Barrage, situated 176 k m. below the dam site.

The drainage basin of the river lies chiefly under the influence of the south-west monsoon and, therefore, the river is in floods during June to October. The catchment area is not fed from the north-east monsoon which affects only the coastal belt of 50 to 60 miles (80 to 100 km., from the Bay of Bengal.

At the time of design by the Central Water and Power Commission, the following data of the Krishna were taken into consideration :—

River discharges as recorded at Prakasam Barrage at Vijayawada situated 110 miles (176 km) below the dam site from 1894 to 1953.

Maximum observed flood was 10,60,800 cusecs (30,000 cumecs) at Vijayawada.

Silt Capacity in the Reservoir

7.4 The catchment area at the dam site 83,087 sq. miles (2,15,195 sq. Km.).

The catchment area at Vijayawada—97,000 sq. miles (25,1200 sq. Km).

With the above data it was assessed that 100 year frequency flood would be 11 lakh cusecs (31,100 cumecs) and thousand year frequency flood would be 19 00 lakh cusecs (53,800 cumecs).

The catchment area at Nagarjunasagar is 83,087 sq. miles (215,195 sq. Km) According to Dr. Khosla's formula, the silt inflow is expected to be 83,000 acre ft. (102 m. cum.) per year. However, Nagarjunasagar is a terminal reservoir and the silt inflow is expected to be much less. Observations have shown that the Krishna carried about 4 T.M. cft. (114 2 m. cum.) of silt annually and that most of it is contributed during the flood season. Part of the silt is likely to get deposited in the reservoir and part is carried away in suspension along with flood waters overflowing the spillway. At the time of design, parametres of distribution of silt along the full depth of the reservoir were not available So the dead storage level has been computed on the basis that the silt is deposited from the bottom of the reservoir upwards. On these assumptions, it was assessed that the useful life of the reservoir would be 500 years.

HYDRAULIC DESIGN

(i) *Spillway Crest Profile*

7 5 An ogee shaped crest profile corresponding to a head of 48 ft (14 6 m) has been provided. The glacis slopes were provided corresponding to the equation ·
(in feet units)

$X^2 = 2.5 H_d y$ — H_d is the head over crest in feet.
X, Y. The co-ordinates of a point in the glacis.

The upstream curve of the crest in Nagarjunasagar has been provided with arcs of two circles of unequal radii.

Extensive model studies were done, to determine the coefficient of discharge of the spillway, side pressures on the spillway piers, and evaluate the performance of the spillway bucket, in the Andhra Pradesh Engineering Research Laboratory, Hyderabad.

(ii) *Spillway Bucket*

To dissipate the energy of the water flowing down the spillway, it was decided to provide a ski-jump bucket A large number of alternatives were tried and studied on the model with mobile bed Particular attention was given to circulation of the bed materials in the bucket and damage caused due to return flow around the training wall and non-overflow blocks Finally a bucket with radius as 70′ (21.35 m) and having an exist angle of 34° was adopted A contraction joint has been provided to separate the structural section of the spillway from that of the bucket The bucket joins the downstream slope of the spillway tangentially at 267.89 ft. level (81 3 m)

Structural Design

7 6 The adequacy of the final design of the spillway and non-overflow sections has been checked in the following conditions :

1. Reservoir at F.R L , no tail water, gates closed condition
2. Reservoir at M W L , maximum tail water, gates open condition
3. Reservoir empty—Construction condition.
4. Drains inoperative, reservoir at M W.L., Max tail water, extreme loading condition.

The following forces were considered for the stability of the dam ·

(*a*) Self-weight of the dam excluding weight of equipment, roadway etc
(*b*) Vertical weight of water on the upstream face batter
(*c*) Horizontal water pressure.
(*d*) Silt pressure on upstream upto a level of 440 ft (134 m)
(*e*) Uplift pressure—50 per cent release of the differential head at the drainage gallery reducing to zero or tail water level at the toe location and acting over 100% of the area

Earthquake forces are not considered as the dam is not situated in a seismic zone.

The following unit weights were taken into account :

1	Weight of random rubble masonry ..	150 lbs /cft. (2 4 gram/cc)
2	Weight of water .	62 5 lbs /cft (1 gram per cc)
3.	Weight of submerged silt	56 lbs /cft (0 9 grams per cc)
4	Angle of repose of submerged silt	30°
5.	Coefficient of friction .	0 70
6	Unit cohesion .	400 p.s i. 28 kg /sq cm.

The following criteria were adopted for safety:

1. No tension in the upstream face of the dam.
2. Sliding factor not more than 0.75.
3. Shear friction factor not less than 4.0.

Stability Analysis

7.7 The calculations of the stability of the overflow and non-overflow dams are given in the following paragraphs. The upstream and downstream face stresses are computed at a number of horizontal sections. Due account is taken of the various openings in the dam. The vertical stresses are given by

$$\delta y = \frac{W}{B} \left(1 \pm \frac{6e}{B}\right)$$

Where W represents the total of all vertical forces acting on any horizontal section.

B is the base width at the section.

e is the eccentricity of the resultant of forces from the centre of gravity of the section.

The sliding factor is computed from the formula—

$$\text{Sliding factor} = \frac{\Sigma H}{\Sigma W.}$$

Where Σ H is the horizontal force on the section and Σ W is the net vertical force on the section The shear friction factor is given by—

$$\text{Shear Friction Factor} = \frac{\Sigma W \tan \phi + CA}{\Sigma H}$$

Where Σ W and Σ H have same significance as in the equation above.

ϕ is angle of internal friction between foundation and masonry.

and C is the unit cohesion between foundation and the masonry.

A is the area of contact at base.

The results of the stability analysis are summarised below: (Table 7.1)

(1 kg/cm.^{2} = 14.22 p.s.i.).

TABLE 7.1

Type of Section.	Condition	Shear Friction Factor	Vertical compressive stress (p.s.i.)		Inclined stress compression p.s.i.	
			U/S	D/S	U/S	D/S
Non-overflow	Reservoir Empty ..	..	311 00	55.0	388 50	91 0
	Reservoir Full, F R.L. Uplift relief 50%	4.75	88.00	218.5	110.00	107 5
	Reservoir at MWL .. .	4.6	3.5	288.0	4 38	173.0
Overflow	Reservoir Empty	..	308 0	59.8	385.0	89 0
	Reservoir Full, F.R L. Uplift relief 50%	4 99	17 25	282 5	21 6	421 0
	Reservoir at MWL	4 98	9.00	291.0	11.25	134 0

Stress Analysis

7 8 For stresses at the upstream and downstream faces, the stability analysis discussed above, gives adequate results. However, it is essential to know the stresses in the interior of the dam, particularly to provide masonry of adequate strength in the various zones according to the state of stress obtaining in each zone.

Stress analysis was, therefore, done for Nagarjunasagar dam for non-overflow as well as overflow sections. The stress analysis is based on the following assumptions :

1. The loads are resisted by the gravity action of a vertical cantilever element having parallel sides unit distances apart.
2. The 'law of the trapezoid' is assumed to apply, that is, vertical stress on horizontal planes vary uniformly from the upstream face to the downstream face of the dam.
3. Horizontal shear stresses are assumed to have a parabolic variation across horizontal planes from the upstream face to the downstream face of the dam.

The method is based on the procedures recommended by the United States Bureau of Reclamation (USBR).

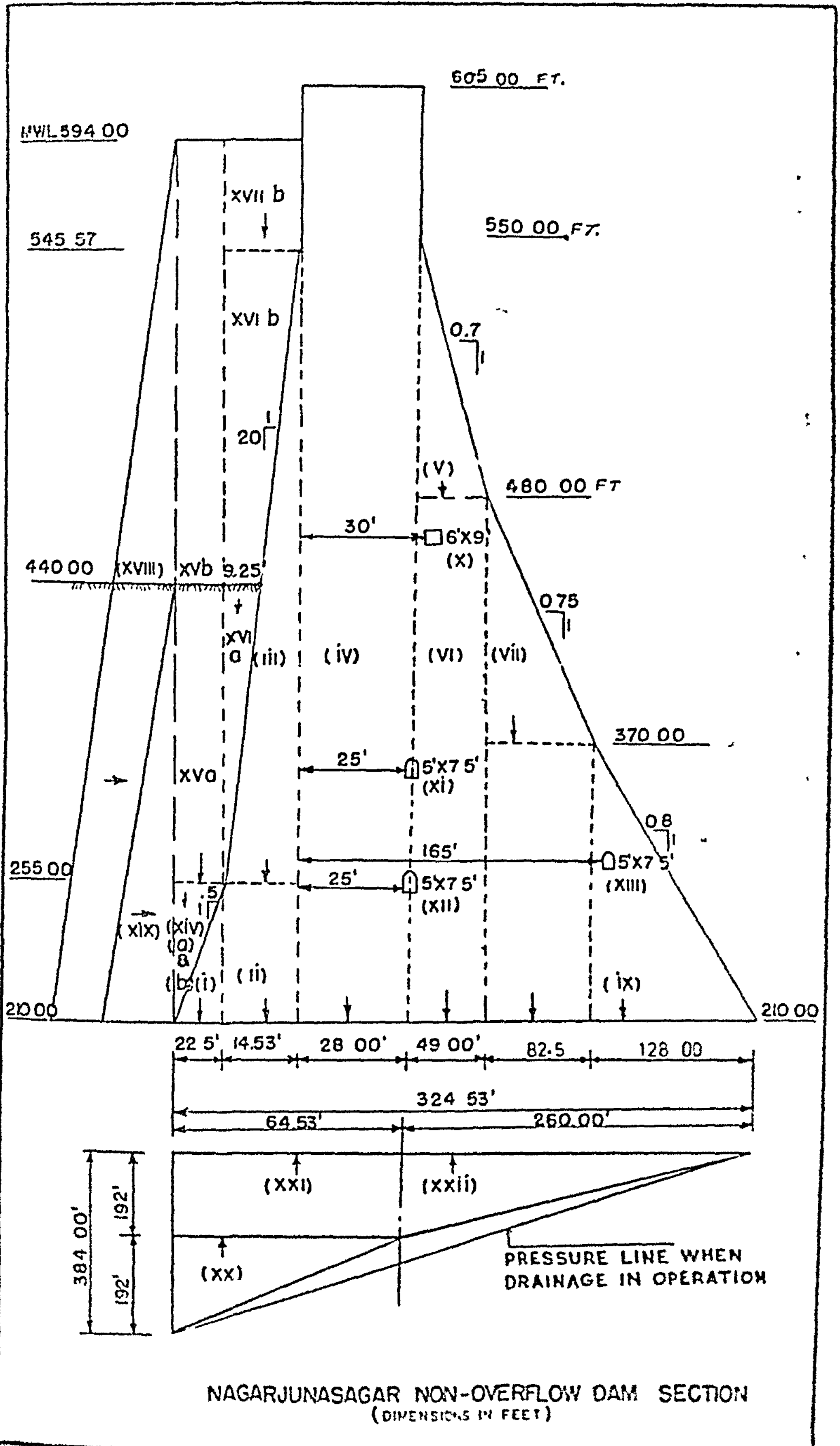
The analysis is given in the following tables 7.2 to 7.6 (in ft. pound units) .

Stability Analysis of Non-overflow Dam Foundation 210.00 ft. (63 9 m.)

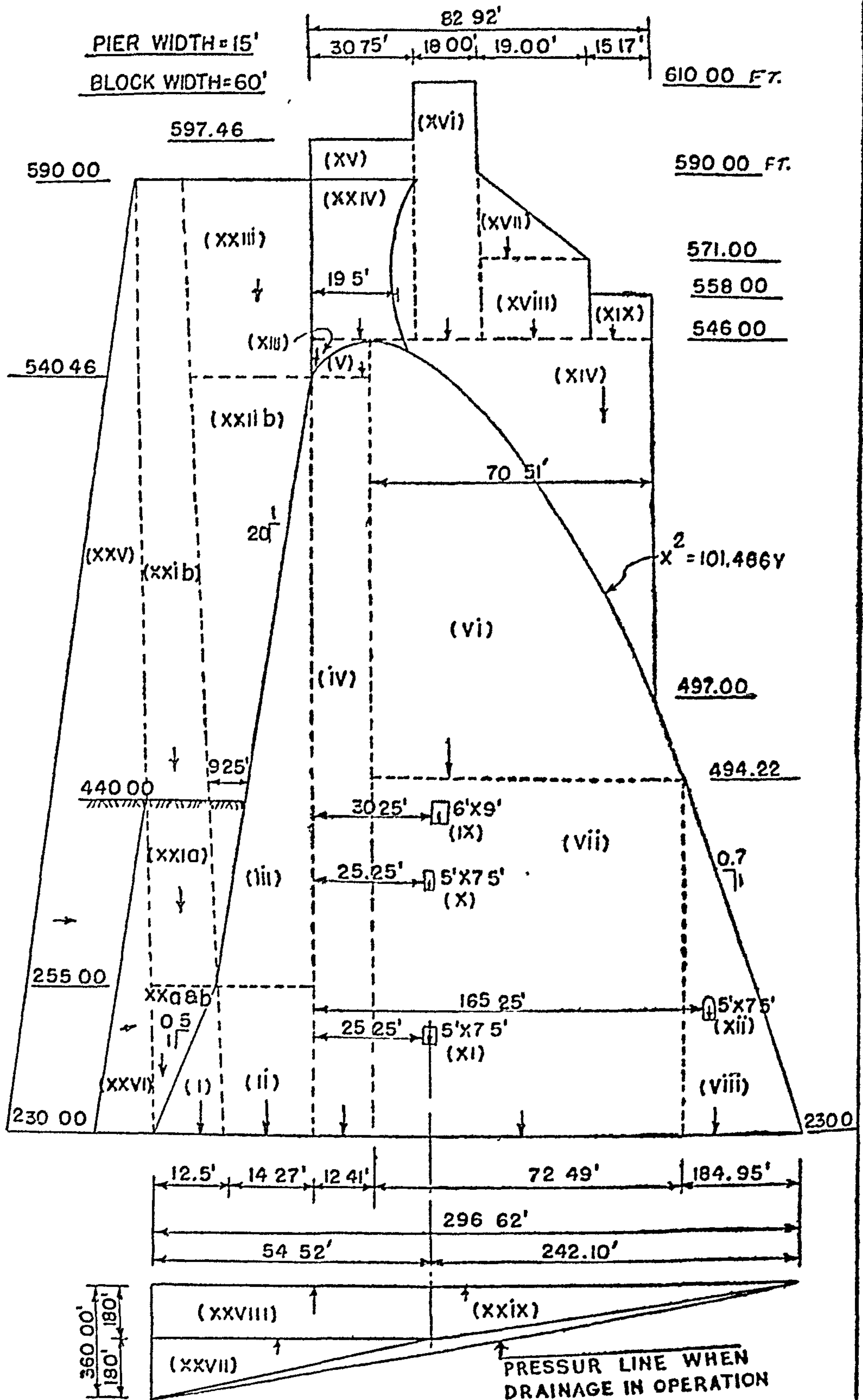
Base width = 324.53 ft. (98 9 m.).

(1 kg/cm^2 = 14.22 p.s.i.).

p s.i. = (lbs per sq. inch).



NAGARJUNASAGAR NON-OVERFLOW DAM SECTION
(DIMENSIONS IN FEET)



NAGARJUNASAGAR OVERFLOW DAM SECTION

TABLE 7 2

Sl No	Particulars	Forces (Kips)		Lever-age FT	Moments about heel k ft lbs	
		Vertical	Horizontal		(+)	(−)
	Weight of Masonry					
(i)	22 5×45×1/2×0 15	75 9		15 00	1,136	.
(ii)	14 53×45×0 15 .	98 0	.	29 16	2,858	.
(iii)	14 53×290 57×1/2×0 15	316 5	.	32.19	10,188	
(iv)	28×395×0 15 .	1,659 0	.	51.03	84,659	.
(v)	49×70×1/2×0 15	257 5		81 36	20,950	.
(vi)	49×270×0 15	1,984 5	.	89 53	177,672	.
(vii)	82.5×110×1/2×0 15	681 0		141 53	96,382	.
(viii)	82 5×160×0 15 ..	1,980 0	..	155 28	307,454	..
(ix)	128 0×160×1/2×0 15	1,536 0	..	239.20	367,411	.
		8,588 4			1,068,710	
	Deduction for Galleries					
(x)	6×9×0 15 . .	8.1		70 03		567
(xi)	5×7 5×0 15 ..	5 6	.	64 53	.	363
(xii)	5×7 5×0.15 .. .	5 6		64 53		363
(xiii)	5×7 5×0 15 .	5 6		204 53		1,150
		24 9				2,443
1.	Total weight of masonry .	8,563 5	..		1,066,267	.

Sl No	Particulars	Forces (Kips) Vertical	Forces (Kips) Horizontal	Lever-age FT	Moments about heel k ft lbs (+)	Moments about heel k ft lbs (−)
	Weight of Submerged Silt on U/S (up-stream) slopes					
(xiv)	22 5 × 45 × 1/2 × 0 056	28.4	..	7 50	213	.
(xv)	22 5 × 185 × 0 056 .	231 0	..	11 25	2,600	..
(xvi)	9 25 × 185 × 1/2 × 0 056 .	47 9	..	25 58	1,227	..
2.	Total weight of Submerged silt on U/S Slopes	307 3	.		4,040	.
	Weight of water on U/S Slopes .					
(xvii)	22 5 × 45 × 1/2 × 1/16 ..	31 6	..	7 50	238	
(xviii)	22 5 × 339 × 1/16 ..	476 0	..	11.25	5,355	.
(xix)	14 5 × 290 57 × 1/2 × 1/16 ..	132 0	..	27.34	3,605	
(xx)	14 53 × 48.43 × 1/16 .	44.0	..	29.76	1,310	
3	Total weight of water on U/S Slopes	683.6	..		10,508	..

Hydrostatic Force					
(xxi) $1/2 \times 1/16 \times 384^2$ . .	.	4,610	128.0	590,000	..
4 Hydrostatic Force Silt Force	..	4,610	128 0	590,000	..
(xxii) $1/3 \times 1/2 \times 0\ 056 \times 230^2$.	..	494	76 67	37,900	..
5 Silt Force .	..	494	76 67	37,900	..
Uplift					
(xxiii) $64\ 53 \times 192 \times 1/2 \times 1/16$	387		21 51	..	8,324
(xxiv) $64\ 53 \times 192 \times 1/16$	774		32 26	..	24,969
(xxv) $260 \times 192 \times 1/2 \times 1/16$ ..	1,560	.	151 20	.	235,872
6 Total Uplift ..	2,721		99 0		269,165
Case I Reservoir empty .	8,563 5			1,066,267	..
Case II Reservoir full up to MWL 594	6,833 4	5,104		1,439,550	..
	(1+2+3−6)			(1+2+3+4+5−6)	

TABLE 7 3

CASE I

RESERVOIR EMPTY

Vertical load	= 8563 5 Kips
lever arm	= 124 5 ft
Base width	= 324 53 ft
e	$= \frac{324\ 53}{2} - 124\ 5$
	= 162 26 — 124 5 = 37 76 ft.
$1 \pm \frac{6e}{B}$	$= 1 \pm \frac{6 \times 37\ 76}{324\ 53}$
	$= 1 \pm 0\ 697$
	= 1 697 & 0 303
Average stress	$= \frac{8563\ 5}{324\ 53}$ = 26 4 kips/sft.
	= 183 4 psi
Vertical stress at Toe	= 183 4 × 1 697 = 311 p s i.
Inclined stress at Toe	= 311 × 1 25 = 388 5 p.s i.
Vertical stress at heel	= 183 4 × 0 303 = 55 0 p s i
Inclined stress at heel	= 55 0 × 1 64 = 91 0 p s.i.

TABLE 7.4

CASE II

RESERVOIR FULL UPTO MWL 594

Vertical load	= 6,833.4 kips Horiz. load = 5104 kips
Lever arm	= 215 0 ft
Eccentricity, e	= 215 00 − 162.26 = 52 74 ft
Maximum and minimum stress	
$= \left(1 \pm \frac{6e}{B}\right) \times$ Average stress (p) .	$= \left(1 \pm \frac{6 \times 52.74}{324\ 53}\right) p = (1 \pm 0.976)\ p$
	= (1.976 & 0.024) p
Average stress .. p . ..	$= \frac{6{,}833\ 4}{324\ 53}$ = 21.0 kips/sft = 146 0 p s.i.
Vertical stress at heel .	= 146 0 × 0 024 = 3 5 p s i.
Inclined stress at heel	= 3 5 × 1 25 = 4 375 p.s i.
Vertical stress at toe . ..	= 146 0 × 1.976 = 288 p s.i.
Inclined stress at toe . . .	= 288 × 1 64 = 473 p s.i
Sliding factor . . .	$= \frac{5104}{6822\ 9}$ = 0 749 which is safe being less than 0.75
Shear friction factor . ..	$= \frac{0\ 7 \times 6822 + 57\ 6 \times 324\ 53}{5{,}104}$
	$= \frac{4{,}775 + 18{,}690}{5{,}104}$
	= 4.6 is safe being more than 4

TABLE 7 5

OVERFLOW SECTION

Considering one foot length of dam & Base width at 230 level = 296 62 ft Pier width = 15 ft (4.56 m.)
Block length 60 ft (18 24 m)

Sl No.	Particulars	Forces (Kips) Vertical	Forces (Kips) Horizontal	Leverage ft	Moments about heel-(k ft pounds) +	Moments about heel-(k ft pounds) −
	Weight of Masonry					
(i)	12 5 × 25 × 1/2 × 0 15	23 4	..	8 33	195	..
(ii)	14.27 × 25 × 0 15 ..	53 5	.	19 63	1,050	.
(iii)	14 27 × 285 46 × 1/2 × 0 15	305.5		22 01	6,724	.
(iv)	12.41 × 310 46 × 0 15	577 5		32 97	19,040	..
(v)	12 41 × 5 54 × 2/3 × 0 15	6 8	.	34 53	237	.
(vi)	72 49 × 51.78 × 2/3 × 0.15	375.0	.	66 36	24,885	..
(vii)	72 49 × 264 22 × 0 15	2,873.0	.	75 42	216,682	..
viii)	184 95 × 264 22 × 1/2 × 0 15	3,665 0		173 32	635,218	.
		7,879 7			904,031	..
	Deductions for Galleries					
(ix)	6 × 9 × 0 15 ..	8.1	..	60 02	..	486
(x)	5 × 7.5 × o 15 .	5 6		52 02		292
(xi)	5 × 7 5 × 0 15	5 6		52 02		292
(xii)	5 × 7 5 × 0 15	5 6	.	194 52	.	1,090
		24 9				2,160
(a)	TOTAL WEIGHT OF MASONRY/	7,854 8	.		901,871	.

WEIGHT OF PIER					
xiii) 12 41 × 5 54 × 1/3 × 0 15 × 1/4	0.8	..	29 87	24	..
(xiv) 70 51 × 49 × 1/3 × 0 15 × 1/4	43 1		92.06	3,968	
(xv) 30 75 × 51 46 × 0 15 × 1/4	59 4		42 15	2,500	
(xvi) 18 0 × 64 × 0 15 × 1/4.	43 2		66 52	2,875	
(xvii) 19 0 × 19 × 1/2 × 0 15 × 1/4	6 8	..	81 85	554	
(xviii) 19 0 × 25 × 0 15 × 1/4	17 8		85 02	1,515	..
(xix) 15 17 × 12 × 0 15 × 1/4	6.8		102 10	697	
(*b*) TOTAL WEIGHT OF PIER	177 9			12,133	
Weight of submerged silt on U/S slopes					
(xx) (*a*) 12 5 × 25 × 1/2 × 0 056	8 7		4 17	36	..
(xxi) (*a*) 12 5 × 185 × 0 056	129 5		6 25	808	..
(xxii) (*a*) 9.25 × 185 × 1/2 × 0 056	47 9		15 58	746	
(*c*) TOTAL WEIGHT OF SUBMERGED SILT ON U/S SLOPES	186 1			1,590	..
WATER ON U/S SLOPES					
(xxiii) 12 5 × 25 × 1/2 × 1/16	9 7		4 17	41	..
(xxiv) 12.5 × 335 × 1/16	262 0		6.25	1,635	..
(xxv) 14.27 × 285 46 × ½ × 1/16	127 2		17.26	2,195	
(xxvi) 14 27 × 49 54 × 1/16	44 2		19 63	867	..
(xxvii) 18 × 44 × 1/16 × 45/60	37 1		35 77	1,329	..
(*d*) TOTAL WEIGHT OF WATER ON U/S SLOPES	480 2			6,067	..

Sl. No.	Particulars	Forces (Kips)		Leverage ft.	Moments about heel-(k ft pounds)	
		Vertical	Horizontal			
	(*e*) HYDROSTATIC FORCE					
(xxviii)	1/2 × 1 × 1/16 × 360² ..	..	4,050	120 00	486,000	...
	(*f*) SILT FORCE					
(xxix)	1/3 × ½ × 0 056 × 210² ..	..	411	70.00	28,800	..
	(*g*) UPLIFT					
(xxx)	54 52 × 180 × 1/2 × 1/16 ..	306 5	..	18 17	..	5,570
(xxxi)	54 42 × 180 × 1/16 ..	613 0	..	27 26	.	16,750
(xxxii)	242 × 180 × 1/2 × 1/16 ..	1,361 0	..	135 22	..	184,034
	TOTAL UPLIFT – ..	2,280 5	..		.	206,354
	Case I Reservoir Empty ..	7,854 8	..		901,871	..
	Case II Reservoir Full	6,418 5	4,461		1,230,107	..
	(*a*)+(*b*)+(*c*)+(*d*)−(*g*)				(*a*)+(*b*)+(*c*)+(*d*) +(*e*)+(*f*)−(*g*)	

TABLE 7 6

OVERFLOW DAM

CASE I—RESERVOIR EMPTY

Vertical load	= 7,854 8 kips
(B) Base width	= 296 62 feet at 230 ft level
Lever arm	= 114.9 feet
(e) eccentricity	$= \frac{296\ 62}{2} - 114.9$
	= 148.31 − 114 90
	= 33.41 ft
Average stress	$= \frac{7{,}854\ 8}{296\ 62}$ Kips. sft.
	= 26 5 kips/sft
	= 184 p s i
$1 \pm \frac{6e}{B} = 1 \pm \frac{6 \times 33\ 41}{296\ 62} =$	= 1 ±0 675
	= 1 675 & 0 325
Vertical stress at Toe	= 184 × 1 675
	= 308 p s i
Inclines stress at Toe	= 308 × 1 25
	= 385 p s i
Vertical stress at heel	= 184 × 0 325 = 59 8 p s.i
Inclined stress at heel	= 59 8 × 1 49 = 89 0 p s.i.

CASE II—RESERVOIR FULL UPTO F R.L 590 00 ft.

Base width	= 296.62 ft.
Vertical load	= 6,418.5 kips
Horizontal load	= 4,461 kips
Lever arm	= 192 feet
Eccentricity, 'e'	= 192.00 — 148 21 = 43.69
Average stress	$= \frac{6,418\ 5}{296.62}$
	= 21.6 kips/sft
	= 150 p s.i.
$1 \pm \frac{6e}{B} = 1 + \frac{6 \times 43.69}{296\ 62}$	$= 1 \pm 0\ 885$
	= 1 885 & 0.115
Vertical stress at heel	$= 150 \times 0\ 115 \times 17.25$ p.s i
Inclined stress at heel	$= 17\ 25 \times 1\ 25 = 21.6$ p s.i
Vertical stress at toe	$= 150 \times 1\ 855 = 282.5$ p.s.i.
Inclined stress at toe	$= 282\ 5 \times 1\ 49 = 421$ p.s i.
Sliding factor	$= \frac{4,461}{6418.5} = 0\ 695$ which is less than 0.75 (safe)
Shear friction factor	$= \frac{0\ 7 \times 6,418\ 5 + 57.6 \times 296.62}{4,461}$
	$= \frac{4,493 + 1,7800}{4,461}$
	$= \frac{22,293}{4461}$
	= 4 99 which is more than 4 (Safe)

Galleries

7.9 A system of galleries has been provided in the dam and serves the following purposes :

(i) Inspection of the interior of the dam

(ii) To facilitate drilling of the grout curtain and provide drainage holes in the foundation.

(iii) Collect the seepage through the porous drain pipes

(iv) Operation of the bulk head gates for the penstocks

There are five longitudinal galleries in all and they are connected to each other by a system of flights of stairs

The size of the galleries is generally 5′ × 7.50′ (1.52 m × 2 28 m) with a semi-circular top The reinforcement design of these gallery sections is based on the results of the photo-elastic tests done by the U S B R , assuming the gallery to be a hole in an infinite plate subjected to axial fields of stress and shear Total tension due to stresses at the centre of the gallery (assumed to be acting on the infinite plate) is computed and adequate steel provided for tension No compressive steel is needed The allowable stress in mild steel is taken as 14,000 psi (970 kg /cm^2) to allow for corrosion of the bars with age.

Extra reinforcements have been provided at the gallery junctions with enlargements made to accommodate the utilities

Spillway Crest Reinforcement

7.10 The spillway crest at any horizontal section not very far from the crest is subjected to an axial load due to the self-weight of the crest and to a bending moment due to water pressure In the top zones, therefore, the criteria of no tension cannot be satisfied. Reinforcements are placed along the profile of the crest designing the section subjected to an axial force and a bending moment In Nagarjunasagar, crest steel was computed as 1″ dia @ 12″ c/c (25 mm dia. at 300 mm centre taken down to 530ft level (161.60 m); on the upstream face of the dam 1/2″ (12 mm. dia) distribution @ 12″ (300 mm) c/c have also been provided

Spillway Piers

7.11 The spillway piers are 15 ft (4 6 m) thick They have a semi-circular nose The piers are of concrete On the crest and glacis a layer of concrete has been provided to make a smooth surface for flow. The spillway pier and crest cap concrete are cast monolithically Analysis

of the piers was done treating the cap concrete, as spread footing for the piers Thus reaction forces were worked out at the base of the cap concrete (the plane of contact of concrete and masonry) and adequate reinforcements were provided. To determine the variation of reaction forces, some photo-elastic model studies were also undertaken at the Central Water and Power Research Station, Poona. This method of analysis, however, it was realized later, gave an uneconomical solution.

Construction Sluices

7.12 Six construction sluices were provided to pass dry weather flows They were 10 ft dia (3 048 m.) on the upstream gradually reducing to 9 ft. dia. (2.74 m.) at the downstream and terminated tangentially to the ski-jump bucket Bell mouth entries corresponding to equation (in feet units)

$$\frac{X^2}{(10)^2} + \frac{Y^2}{(10/3)^2} = 1\ 0$$

were provided.

The construction sluices were plugged later on

The structural design of the sluices assumes them as cut-outs in the infinite plate subjected to appropriate stress fields.

Block Lengths and Location of Contraction Joints

7.13 The Nagarjunasagar masonry dam is divided into 79 blocks. Eleven blocks are 50 ft (15.25 m) long each, 50 blocks 60 ft. (18.3 m.) each, 12 blocks 70 ft. (21 35 m) each and six blocks are of varying lengths from 25 ft to 85 ft. (7.5 m. to 26 m.)

7.14 Different lengths have been provided for the various blocks for the following reasons :

(*a*) More than one penstock could not be provided in one block, if the block length is not to be unduly long Therefore, one pipe is embedded in one block and a minimum length of 50′ (15 25 m) has been provided.

(*b*) Blocks 71 to 75 are 70 ft (21.35 m) long to accommodate power and right canal sluices

(*c*) Blocks 5, 7, 70, 70A etc varying in length from 25 ft to 85 ft (7.5 m to 26 m.) for reasons of acceptable foundation grades and facility in construction

(*d*) The procedure of providing a contraction joint in the masonry dam has been to plaster with cement mortar 3/4" (19 mm.) thick the end face of the adjoining block lift and build up masonry against it.

(*e*) A system of two 16 gauge copper water stops was provided with a square hole in between them, filled with asphalt to form a water tight membrane bounded by the water stops.

Instrumentation of Nagarjunasagar Dam

7.15 To verify the correctness of the analysis of a structure. it is essential to monitor its behaviour to various loads. The instrumentation in dams has a two-fold purpose :

(i) To assess the actual state of stress, deformation etc in the dam and correlate it with the computed stresses and deformations.

(ii) To have forewarning of any unusual state of stress or behaviour so that timely remedial measures could be taken.

The second aspect is of great importance, particularly for dams, as their failure is often catastrophic. Dams are complex structures and their analysis involves various simplifications and assumptions needed to apply in practice the results of theoretical principles of engineering and mechanics. Further, dams are built to serve for long periods and ageing effects can take place during their lives The instruments embedded in the dam during its construction, thus, provide a means of checking the safety of the structure. Resistance type instruments were embedded in the Nagarjunasagar dam The choice of this type of instruments was made purely from the point of view of their easy availability, popularity with the engineers and experience with these instruments on similar structures, notably the Bhakra Dam.

Types of Instruments

7 16 In the Nagarjunasagar masonry dam, thermometers, stress meters, strain meters, joint meters, uplift pressure pipes and plumb line have been provided In the earth dam cross arms and Piezometers were provided. One hundred and thirty Carlson type instruments are embedded in monoliths 6, 14, 21, 26, 37, 43, 59 and 70A. The number of instruments, their type and their distribution and location in various blocks are shown in the following Table 7.7.

TABLE 7.7

Statement Showing Details of Instruments Embedded in Nagarjunasagar Dam

Elevation (level feet)	Block No	Resistance Thermo-meters	Stress meters	Strain meters	Joint meters	Pore Pressure cells	Uplift pipes	Piezo-meters	Plumb-bob
245	14 Toe	8	..	..	..	..	..	..	1
262	14	8		..	..	..	4	.	
250	15 Adit	3	.	..	..	..	..	.	..
250	20	..	..	..	..	.	10	.	.
..	21	..	..	..	..	..	4	.	.
250	24	..	..	..	..	.	10	..	.
250	25	..	..	..	..	.	.	5	.
265.5 262 262 5 261.25	26 Toe	4	..	..	..	.	.		.
246	37 Toe	.	4	12	.	10	.	.	.
250	37	8	3	..	4	.	.	..	.
250	39	..	..	..			6	..	..
250	39	.	..	..	..	..	2	..	..

264	..	..	43	1	.	..	.	..	..	..	..
250	.	..	44	..	.	..	..	..	10	..	..
250	..	..	55	..	..	.	..	..	10	..	..
250	.	..	51	.	..	.	..	..	..	60	..
250	..	.	55 Too	.	.	..	..	..	6	..	..
245	..	..	59	8	3	..	..	.	10	..	.
262	.	..	59 Too	8	4	6	.		4	.	..
250	..	.	64	..	.	..	.	.	10	..	..
250	..	..	6	.	..	4	4	..	..	.	..
350	.	..	37	4			.	4	..	..	..
351	..	..	59	6	..	..	..	..	..	..	
350	..	..	70	..	.	..	4	..	..	.	..
420	..	..	70	..	..	..	1	.	..	.	..
455	..	..	6	..	..	10	1	..	..	.	..
522	..	..	21	1	..	..	..	..	..	..	..
465	..	..	5/6	..	..	..	1	..	..	..	
470	..	..	5/6	..	..	.	1	..	..	.	.
435	..	..	5/6	..	.	..	1	..	..	..	..

DESCRIPTION OF INSTRUMENTS

A brief description of the various instruments is given below:

Temperature Recorders (Thermometers)

7 17 In dams, temperature changes are the chief causes of volume change and stress Temperature changes arise from both external and internal causes The temperature of the faces of the dam is affected by ambient temperature, the temperature of reservoir water and seasonal changes in weather conditions. This is important, since most cracking begins on the surface. This makes it desirable to measure boundary temperatures in a dam. Just as important as external heating and cooling, the heat of hydration of centre is significant : i.e., the heat from within the dam due to the chemical reaction of cement combining with water Most of the heat of hydration develops during the first few weeks after mixing, but it continues for many years after the dam is completed Thus, to determine the effect of temperature on the stress due to volume changes in a dam, the temperature should be measured at a number of points within the dam as well as at the boundaries.

Some interesting observations of temperature studies in the Nagarjunasagar dam are noted under :

Block 37 · Thermometer (T-32) near the downstream, which was embedded in 1960, recorded a temperature of 99.3° F' which gradually dropped to 82° F. by 1964. Thereafter, the temperature remained around 82°F. Though there were fluctuations in the atmospheric temperature, there is very little reflection in the temperatures recorded by these instruments

In the centre of the dam, the maximum rise in temperature soon after embedment was recorded as 102 4°F by T-35. The temperature at the base of the dam had dropped to 85°F. by 1967. The temperature at higher elevations had gradually fallen to 90°F. by 1967.

In the upstream face of the dam the temperature became steady around 85°F. quite from 1965 onwards

The isotherms for April, 1960, which represent the temperature condition soon after their embedment, reveal that the temperature has risen from the upstream face to the downstream face from 84°F. to 94°F. In June, 1964, it was observed that the temperature on the outer faces was around 85°F. and in the centre 87°, thereby indicating that the temperature in the masonry nearer to the face cooled earlier due to external influence.

Studies of the temperature observations, in the centre of the dam indicate that the initial temperature in the masonry near the base of the dam was between 95°F and 98°F and that the temperature cooled down to 90°F. by 1967 It is interesting to note in this case that the temperature in masonry at 350 ft cooled faster and fell to 85°F by 1967

Isotherms for June and December of each year from 1965 show an increase in the temperature gradient from the upstream face towards the centre from 84°F to 91°F. The temperature near the upstream face is more or less steady, varying from 84°F to 81°F between 1965 and 1969, whereas the temperature variation along the downstream face is marked as ranging between 83°F to 95°F from the base of dam to 350 ft level. This is due to the external atmospheric influence on the downstream face There is no conspicuous change in the temperature in the centre of the dam, which was around 90°F.

In all the thermometers, a general trend was observed of increase in temperature soon after embedment. Most of the thermometers were embedded in the forenoon of the day To ascertain whether this sharp rise in temperature is due to the heat of hydration or the effect of increase in the atmospheric temperature, hourly rise in temperatures of the atmosphere and the embedded thermometers were compared From this it was inferred that with a slight amount of corrections the initial rise is exclusively due to the heat of hydration

Pore Pressure Measurements

7.18 One of the uncertainties in the stability of a massive structure of stone or concrete is the water pressure through the seams of the foundation rock, in the pores and in possible joints in the structure itself. These pressures are measured by an installation of pore pressure cells in the body of the dam from the upstream face Measurements will have to be made at selected points in the foundation as well as in the structure itself. For relief of the pressure, most of the large dams are provided with drains. One purpose of the pore pressure measurements is to check adequacy of the drains The measurement requires a device which needs practically no flow of water. The Carlson pore pressure cell is suitable for this purpose This is similar to the stress meter, except that the water pressure filters through a porous stone and deflects the elastic diaphragm, whose movement is measured electrically.

In the Nagarjunasagar dam, ten pore pressure meters have been embedded in block No 37, of which six are located at 275 ft. level and the rest four at 340 ft level All the cells at 275 ft. level were in working order for a few years except pore pressure meter P2 which went out of order within

two months of embedment. Amongst the pore pressure meters located at 240 ft level all the cells are in working order except P 7 which went out of order within two months of embedment.

Upto 1965 most of the pore pressure cells located at 275 ft. level indicated positive pressures within the range of 10 to 30 p s.i. Pore pressure cells viz P. 3 & P. 4 have registered negative pressure. It is seen that by and large pore pressure cells have responded to the changes in the reservoir level.

The pore pressure cells located at 340 ft level have recorded negative pressures

It has not been possible to establish any correlation between observed and computed values of pore pressures

Overall study of the pore pressures in 1967 indicated a steady pore pressure ranging between 10 and 40 p s.i. (0.7 and 2 8 Kg /cm.) One cell which was located close to the draining pipe indicated negative pressure Cell No. 10 indicated on an average a pressure of 15 to 20 p s.i. from May, 1964 to April, 1965. When the reservoir started filling up, there was simultaneous increase in the pore pressure to the extent of 68 p s i (4.76 Kg /cm ^{2}) It is seen that between the observed and assumed pore-pressures in the design, the former is higher.

Stress and Strain Meter Observations

7 19 The design of a dam is based on the determination of stresses in the various portions under the assumed conditions of loading Therefore, the stress in the actual structure is of prime concern to the designer.

The Carlson stress meter directly measures the stress. In some cases, it may be necessary to measure the strain and then compute the stress. The measurement of both stress and strain independently gives an opportunity for checking the reliability of the results. Besides, measurement of strain is essential where tension is expected because the stress meter measures only compressive stress.

In the Nagarjunasagar dam stress meters are located near the base of the dam in Blocks 37 and 59. Seven stress meters were installed in Block 37 in 1959 and seven in Block 59 in 1960. Some meters which were not properly embedded in masonry showed incorrect readings. The observed stresses require to be compared with the calculated stresses with reference to the water level in the reservoir. It has been noticed that the stresses as observed and calculated were comparing fairly with each

other in the case of Block 59 Whereas in the case of the stress meters embedded in Block 37, there is no tally between the observed and calculated values of stress.

Uplift Pressure

7.20 Pipes for measuring uplift pressures are located in nine blocks of the dam The pressures noted from one uplift pipe in block 24 ranged from 25 to 46 pounds per square inch (1 73 to 3 18 kg per cm ^{2}) from 1967 to 1970 and the uplift pressures in the pipe in Block 20 ranged from 20 to 38 pounds per sq inch (1 382 to 2 62 kg cm^2) These pressures are well within the design criteria values

Joint Meters

7.21 In a massive structure much of the temperature rise caused by the heat of hydration of the cement has to be properly taken care of, else it could easily be deformed When the temperature drops, contraction joints open out It is important to measure the opening of the contraction joints Much information on joint openings is gained from internally located joint meters.

In the Nagarjunasagar dam 14 Carlson elastic wire type joint meters have been installed in the joints between blocks and also between the foundation face and Blocks Of these, two are located between blocks 36 and 37 and two between blocks 37 and 38 Five joint meters were embedded in each of the Blocks 6 and 70A, between the blocks and the foundation rock

Joint meters 7 and 8 between Blocks 36 and 37 are located at 250 ft level (76.2 m) and 95 feet (28 95 m) and 10 feet (3 048 m) downstream of axis of dam respectively During 1966, the observations indicated joint opening during the major part of the year reaching a maximum of 0 4575 (mm) The joint started closing and the observation indicated closure throughout the period 1967 to 1969. Joint meter 8 was also installed in 1959 at the same elevation. This indicated an opening between the blocks throughout The maximum opening was 0 046″ (1 169 mm) in August, 1966 Thereafter, the gap started closing gradually Except for minor fluctuations, by 1969 the gap had been reduced to 0.009″ (0.23 mm).

Observations on joint movement between foundation rock and the block were available from joint meter 5 installed in Block 6. This joint meter was installed at a levl of 470 ft. (143 m.) 55 feet (16.75 m) down-

stream of axis of the dam, between the abutting foundation rock and the block The opening is in the order of 0 004″ (0 10 mm).

Joint meter 1 indicates mostly opening, but the magnitude is small i.e around 0.004″ (0.10 mm) After 1969, it registered a maximum opening of 0 016″ (0 40 mm.) in the latter half of 1970. Joint meter 4 registered only opening throughout The opening does not increase with time, but fluctuates around 0.016 (0.40 mm). This may be due to the slow process of cooling i e about 85°F. in 1966 to only 82° in 1970.

RESUME

7.22 This chapter has been specially introduced for the scientists and engineers of the present and posterity for their guidance and to appreciate the actual methods adopted in the design of this gigantic masonry sturcture, ever built in the history of masonry dams. The fact that the structure has safely withstood several floods after completion at full reservoir level and the fact that its seepage is much less than that of a concrete dam of equal height, is a testimony of its performance. While designing structures, the engineer has to assume several design criteria and conditions of loading A structure having been built under these assumed conditions, the engineer has the concern to verify the actual stress developed in the structure It is for this, that various instruments are embedded at different locations. The instruments of Nagarjunasagar dam, have given the stresses, which fairly compare with those calculated as per design.

The observed stresses from the instruments give the indication whether the actual structure has been safely designed. In case the built structure were underdesigned, we have to take safety measures for strengthening it and on the other hand, if it is over-designed, we could effect economy in future designs of the structures to be built.

CHAPTER VIII

MASONRY VERSUS CONCRETE FOR DAMS

History of Masonry Dams

From time immemorial, masonry dams have played a vital role, in supplying water to a number of cities, for irrigation of dry lands, as sources of power and for controlling floods In the history of human civilisation, masonry dam construction dates back to 2950 B C on the Saddel-Karfara dam situated some 32 km south of Cairo in Egypt.

8.2 In 400 A D., the Jewish communities built the Marib dam, the biggest of its kind in South Arabia The dam was built in masonry with lime concrete matrix It was 5 54 m wide at its base and 8 5 m high and fitted with a low level stone outlet pipe through which the stored water could be drawn off

8.3 In ancient times, the Romans and the Indians were the greatest engineers. They learnt their engineering from the Greeks who had a marked understanding and developed technology. The Greeks were the first to make hydraulic lime and used puzzolana in mortar. Puzzolana is a volcanic dust first found at puzzuoli near Naples, which forms with mortar a cement that will set in air or water. The Romans employed a large number of Greek engineers and workers on their projects in the first and second centuries

8 4 A notable curved dam built in masonry was built by the Romans in North Africa at Kassorine, about 225 km , south-west of Tunis. It was discovered late in the nineteenth century. This dam was built in the second century A D to supply irrigation water to the town of Cillium The discoverer of the dam, Henri Saladdin, has commented on the fine masonry of which it was built The dam was 10 m high with the crest width 4 9 metres and base width 7.3 m.

8 5 As far back as the second century A D. in India Chola Kings constructed a masonry dam across the Cauvery near its mouth. The dam was built in masonry laid in clay, 309 m long, 18 3 m wide at base and 5 5 m. high This dam represents one of the most remarkable of very many old dams and tanks which are still in use

8 6 The Romans built several dams in North Africa for water supply, flood control, water retention and soil conservation When sufficient silt had accumulated in a dam, it was dredged out and used for agriculture, the required irrigation being achieved by valley run-off.

8 7 All the masonry dams built by the Romans followed standard construction practices in steep and narrow water courses, when good rocky foundation was available. In the dam construction, rubble and earth cores were used. The water faces of the dams were treated with *Opus Signinum*, a type of plaster made up of hydraulic lime mixed with crushed brick powder. The upstream face was stepped and many of them were provided with buttresses on the downstream side for added strength

8 8 Around the sixteenth century, the Band-e-Saraj dam was built 27 km from Gazni in Afghanistan. The author had the opportunity of visiting this dam in 1973. It was built in masonry with hydraulic lime The dam is 36.6 m. in height, built with disintegrated granite stones with uneven courses varying from 225 mm. to 300 mm in depth The water face batter is 1 in 12 and the air face batter is 0.8 to 1.0. The dam is 260 m. in length and has no contraction joints. There are no cracks in the structure and there is no seepage of water through the masonry joints.

8 9 The earliest masonry dam built in north-eastern United States was by English colonists In 1681 they settled in New Brunswick, New Jersey and in 1743, they built a masonry dam across the Raritan river for water supply. The dam was strengthened in 1780 and was in continuous usage until it failed in 1888.

It was in the nineteenth century that the need for the construction of high dams was felt and the challenge was met with great success. Dams played an outstanding part in the industrial revolution and in the uplift of social and economic conditions.

8.10 In France, the Crosbois dam was built in masonry in 1837. It was 22 2 m in height and 550 m long. One important aspect noted in this dam was that it was subjected to elastic deformations in successive filling and emptying Measurements were recorded carefully and it appears to be the first occasion when engineers realised that masonry dams behaved elastically These studies began for the first time in France

8 11 It was around 1800 A.D that the outstanding masonry arched dam; the Meer Allum dam was built for water supply to the city of Hyderabad in South India It is the earliest known example of a buttress dam of the multiple-arch type, which was never tried before. The dam was built by Indian engineers in collaboration with British and French engineers. It has a maximum height of 12 2 m. and 762 m long in a curve It is divided into 21 semi-circular arches whose spans range from 21.3 m. at the ends to 44.8 m near the centre. Each arch

is stepped, with a constant thickness of 2 60 m. at the crest. The arches are supported by a series of buttresses, each 12.8 m long and 7.3 m. thick. The tops of the buttresses are level with the crests of the arches. The reservoir has a capacity of 9 87 m cu m. of water. The overflow is discharged partly through a spillway at one end, while the rest flows over the crest Though the dam is nearly two centuries old, there is no damage either in the masonry or mortar, nor are the foundations undermined. This dam supplies water to the city of Hyderabad to the present day

8.12 Around 1850, the British engineer, Sir Arthur Cotton, played an eminent role in building masonry structures across the Godavari, Krishna, Tungabadra and Mahanadi

8.13 It was at the end of the 19th century that the 53.3 m high Periyar dam was built in masonry. The 44.5 m. high Krishnarajasagar dam in Mysore, built in 1920; 68 5 m high Mettur dam built across the Cauvery in Tamil Nadu completed in 1934; the Nizamsagar dam 30 m. high built in 1931 across the Manjera in Hyderabad State; the Tungabhadra, the Hirakud and a few other dams, are outstanding examples of the traditional masonry construction in India, accomplished in the first half of the twentieth century.

8.14 In 1911, the Roosevelt Dam was built in the U S A It was the largest masonry structure of its time in the world It is 86 6 m high and the electric power produced at this dam was sold to Phoenix (Arizona).

8.15 The application of concrete to dam building had its beginning around 1900. Much research has since been done in regard to the strength and utility of the material. In 1916, the Hoover Dam construction was taken up in concrete across the Colorado river. The dam is 222.5 m high, with a crest width of 13 7 m and a length of 359 7 m. It is composed of 2 67 m. cu. m. of concrete. Associated with this immense concrete structure is a massive power plant equipped with gigantic generators which have a total rated output of a million horse power.

8.16 In 1948, the Bhakra dam, a gigantic concrete structure, was built in India across the Sutlej In addition to irrigating 1.46 m hectares, the dam has an installed capacity of 1050 mega watts of power

8.17 In 1954, when the construction of the Nagarjunasagar dam, the highest and the largest masonry structure in the world, came up for review, the suitability of masonry for such a structure of 124 7 m height was doubted As this high dam involved a high stress of over 22 kg /sq. cm, the technological advance made in the use of cemen

concrete was considered to solve the problems of employing a big labour force and assure considerable speed in construction, as complete data and tests are available to assess the quality and strength of concrete. Masonry construction was doubted and considered unreliable as there was no proof whether the masonry could withstand a stress of over 22 kg per sq cm.

First Recommendation of Committee of Engineers

8 18 As per the report on the Nagarjunasagar project, prepared jointly by the Hyderabad and Andhra Governments in 1954, the proposal was to construct the dam with random rubble masonry in red cement mortar (1 cement . 4 sand), with 2.7 m. thickness of the dam on the water side with (1 cement : $2\frac{3}{4}$ sand). Surkhi (finely powdered burnt clay) was used, replacing twenty per cent cement. The Control Board of the project, on the suggestion of the Central Ministry of Irrigation and Power, appointed a committee of engineers to recommend suitable types of materials for the construction of the dam, particularly in places where stresses higher than permissible in rubble masonry might be developed.

Its members were—

(i) Dr. K. L. Rao, Chief Engineer of the Central Water & Power Commission ;

(ii) Mr M. S. Thirumala Iyengar, Chief Engineer of the Hirakud dam project ,

(iii) Shri L Venkatakrishnan, Special Chief Engineer (Irrigation), Andhra State ;

(iv) Shri D. V. Rao, Chief Engineer, Irrigation projects, Hyderabad

(v) Mr. M. Jafer Ali, Chief Engineer, Nagarjunasagar dam and

(vi) Mr. George Ooman, Director (Designs), Central Water & Power Commission.

The members examined various aspects of problems during discussions on November 17, 1955 and August 28, 1956 The materials that were considered were—Concrete, rubble concrete and rubble masonry (with concrete provided in highly stress zone of rear toe).

The merits and demerits of the materials were discussed on the aspects of :

(*a*) Strength and factor of safety to be allowed

(*b*) Cost of construction

(c) Period of construction

(d) Requirement of machinery

(e) Requirement of cement

(f) Employment potential

The factors are discussed below.

(a) *Strength and Factor of Safety* Data available from the Mettur dam, as furnished in the History of Cauveri-Mettur Project, showed that the strength of mass concrete with surkhi of mix (1 cement 3 sand·6 aggregate) was 180 kg per sq. cm The factor of safety for concrete was taken as 4, based on strength at the end of one year. Regarding the strength of masonry, tests were being conducted on masonry at Hirakud (India) and at Denver (U S A.) The test results were not yet available. Therefore, the strength of mortar was taken as that of masonry The factor of safety of 8 based on the strength at the end of one year was recommended. The following strengths of red cement mortar were noted from the History of Cauveri-Mettur Project:

(i) Average strength of red cement mortar (20% replaced by surkhi) 1 : 4 at the end of 28 days .	131 kgs. per sq cm	
(ii) -do- 1 3 red cement mortar -do- .	166	-do-
(iii) Mass concrete with surkhi admixture (1 3 6) .	180	-do-
(iv) General mass concrete mixture (1 . 3 . 7)	170	-do-

As per the observations of the members of the stress committee, the strength of concrete mortar used in rubble concrete was 338 kg per sq cm at the end of 90 days and recommended a factor of safety of 4 to 6. But rubble concrete (German masonry) was used only in one dam in Germany and it had also been used at Koyna in India

(b) *Cost of Construction*. The alternative proposals were worked out for building the dam in concrete, rubble concrete or rubble masonry with concrete in highly stressed zones i.e above 22 kg per sq cm. The data worked out by the Chief Engineer, Koyna, for rubble concrete of Koyna dam was studied The rates worked out for the Nagarjunasagar dam were · Concrete Rs 53 per cu m, rubble concrete Rs 47 per cu m, and rubble masonry with 1 . 4 red cement mortar Rs 40 per cu m.

The comparative cost of the dam was :

With mass concrete ..	Rs. 241.4 millions
With rubble concrete .	Rs. 220.4 millions
With rubble masonry (concrete in highly stressed zones) ..	Rs. 201.7 millions.

Three alternatives i.e. rubble masonry-cum-concrete, was considered cheaper and feasible, as abundant skilled and unskilled manual labour is available in this region.

(*c*) *Period of Construction* · With the favourable condition of the dam site and availability of extensive area for working, the out-turn for all the three materials i.e., concrete, rubble concrete and rubble masonry, was expected to be the same.

(*d*) *Requirements of Machinery* · In the case of either mass concrete or rubble concrete, it requires time for procurement of machinery and its installation. For mass concrete, machinery is required for batching mixing, laying in position and cooling. On the other hand, masonry could be started advantageously with less machinery. It was proposed to mechanise only the feedings of the materials and the construction of masonry was to be done by manual labour.

(*e*) *Requirement of Cement*. More cement was required either for concrete or rubble concrete than for rubble masonry. Cement being a costly and scarce commodity, rubble concrete has preference in this respect. Incidentally, with the reduced consumption of cement for masonry work, the heat of hydration does not pose any problem and special elaborate and expensive arrangements for cooling are not required.

(*f*) *Employment Potential :* For skilled labour required for masonry construction, a large labour force of masons, stone dressers and stone cutters, was available in the locality. In addition, there were thousands of unemployed unskilled labour.

CONCLUSIONS OF THE COMMITTEE

8.19 The committee examined the above factors, the unit rates for masonry and concrete. The difference in cost between the two classes of construction was of the order of Rs. 12.5 per cu. m. Thus the difference in the cost of concrete and masonry dam was Rs. 40 million. Therefore, they recommended masonry to be adopted for the construc-

tion of the Nagarjunasagar dam. The committee came to the following conclusions ·

(i) Rubble masonry with 1 : 4 cement mortar could be used for the dam where the principal compression stress does not exceed 16 4 kg per sq. cm

(ii) On the upstream face of the dam for a thickness to be specified by the designs organisation a richer mix of 1 3 with puzzolana would be desirable to ensure impermeability, even though the stresses are below 16 4 kg per sq. cm.

(iii) For locations where the stress is between 16 to 22 kg per sq cm , the committee recommended rubble masonry with 1 : 3 mortar.

(iv) In locations where the stress is higher than 22 kg per sq cm. cement concrete was recommended with a factor of safety of 4 The committee, however, agreed that rubble concrete could be trusted to replace concrete provided it could fit in with the construction plant layout

(v) It was also agreed that the rear face of the spillway section of the dam should be finished with concrete of high quality (exact thickness was to be decided by the Designs Organisation)

The plan shows the zoning of the materials

8 20 After these recommendations were submitted, the Chairman of the Central Water and Power Commission visited the Oker dam in Germany and furnished details of rubble concrete. The total quantity on concrete-cum-stone (rubble concrete) in this dam is of the order of 1,45,000 cubic metres This work took about three years The maximum outurn obtained was 6000 cubic metres in two shifts This is the only dam in Germany built by this technique

While better quality could be expected by using this technique, it was felt that the huge quantity of 5.3 million cubic metres involved in the construction of the Nagarjunasagar dam could not be completed in 7 to 8 years if rubble concrete was used It was, therefore, felt that for this large quantity, plain concrete may, in fact, compete favourably with rubble concrete The committee recommended that the dam should be built in rubble masonry, with cement concrete or rubble concrete in highly stressed zones (higher than 22 kg per sq cm). The choice between concrete or rubble concrete was left to the discretion of the Chief Engineer

8.21 At the suggestion of the Chairman of the Central Water and Power Commission, Mr. Slocum, Construction Superintendent, Bhakra

dam project, paid a visit to the Nagarjunasagar dam project in March 1956 and sent a report to the Chief Engineer of the Nagarjunasagar dam. In his letter of April 14, 1956 addressed to the Chief Engineer, Mr. Slocum expressed the view that ultimate sizeable economies would be the result of constructing the dam of some standard specification concrete, rather than of grout laid masonry. He suggested that the dam be built in concrete by deploying a large fleet of machinery to be imported. His advice was shelved, it being costly and not labour oriented.

Physical Properties of Masonry

8.22 Weight, modulus of elasticity, the co-efficient of expansion and the specific bond surface area, play an important role in the design of gravity dams The weight of masonry per cu.m is 2.49 tonnes as against 2.33 tonnes for concrete (1 cement : 3 sand : 6 aggregate) The co-efficient of expansion of masonry suffers less from temperature changes It is .0000035 for masonry and .000006 for concrete. The construction joints in the case of masonry need not be placed close as in the case of concrete dams. The joints in masonry dams are placed varying from 18 to 37 metres, as it was done in Mettur, as against 18 m in the case of concrete The modulus of elasticity for both concrete and masonry is 0.14×10^6 kg. per sq. cm Regarding elasticity there is no difference between masonry and concrete.

Normally, the elasticity of the foundation rock determines the stress concentration and non-linear distribution of stress at base sections. Since the foundation rock is the same, whether the dam is built in masonry or concrete, and since its elasticity is higher than that of concrete or masonry, this factor does not require consideration.

The foregoing review of data shows clearly the outstanding advantages in the use of masonry *vis-a-vis* concrete for the construction of the dam.

Structural Strength of Masonry

8.23 In the absence of regular tests, it was not possible to convince the engineers that they have a case to build the gigantic Nagarjunasagar dam entirely in masonry. Speed of construction, early completion and quality control became doubtful. In the case of concrete, the tests could be easily conducted on 150 mm cubes which require small capacity testing machines, readily available. So stresses upto 44 kg. per sq cm were allowed in concrete in the case of 220 m high boulder dam in U S.A. For lack of a proper testing machine, the strength of masonry was placed on par with the strength of mortar which formed a part of the masonry. Therefore,

only a maximum stress of 22 kg per sq cm was allowed in the Wilson dam of 82 3 m height built in Indiana It was considered that this limit might not be exceeded Based upon these reasons a low factor of safety of 4 was considered adequate for concrete, while a high factor of safety of 8 to 10 was assumed for masonry. The factors of safety were based on the strength of mortar In the case of masonry construction, the quantity of mortar used forms only a small part as compared to that in concrete The modulus of elasticity of stone is generally higher, about 0 28×10^6 kg per sq cm , whereas that of mortar is about 0 14×10^6 kg. per sq. cm Since direct contact exists between individual stones as in the case of metal in concrete, the share of load transmitted through the stones is larger than that through the mortar So the procedure of assuming the strength of masonry to be the same as that of mortar used and adopting a factor of safety of 10 has been considered outdated and conservative However, in the absence of large testing machines the danger of applying strength of small specimens to large bodies of work is not considered realistic, as any error is multiplied manyfold Therefore, the strength of masonry remained indeterminate in the absence of regular tests

The Need for a Giant Testing Machine

8 24 The Karlsruhe Laboratory in Germany has a 5,000 ton testing machine In the U S A , there are a few 2 25 million kg universal testing machines. One such machine is in the U S. Bureau of Reclamation The U S machine extends 15 m above and 4 8 m below the laboratory floor and has a gross weight of 337.5 tonnes It can test specimens as long as 10 m either in compression or tension. To get a testing machine of such proportions and capacity fabricated and erected in India, would have cost a great deal in hard currency.

Original Idea of Dr K. L Rao

8.25 It was a simple and dynamic idea of Dr. K. L Rao, who was working at that time as Chief Engineer in Designs and Research in the Central Water and Power Commission He suggested an arrangement for resisting a 2,000 ton reactive force or stress by natural means such as a rock face in a stone quarry, in lieu of the usual large-sized screw threaded steel columns Thus, a testing apparatus could be improvised with four 500-ton hydraulic jacks suitably arranged for transmission of the four and half million pound thrust on a specimen

Based upon the above conception, Mr. M S Tirumala Iyengar, Chief Engineer of Hirakud dam project, improvised an Indian apparatus

by boring a large cave in a granite hill at Laxmi Dungri of Hirakud dam to house the testing equipment. The design has been perfected, with four hydraulic jacks bearing against a set of girders and a pyramidal loading block on the test specimen. The test block itself rests over a steel framework which spreads the load to a sufficiently large area of the floor of the cave. The jack heads, instead of directly bearing against the roof, transmit the reaction or the thrust through a spreading cap on to two grills, 0.84 and 0 37 sq. m and thence to the roof of the tunnel.

The loading system rests on two cross-beams which press down on the specimen block The 500 ton hydraulic jacks were then gradually operated by a motor so as to exert the required load over the specimen to the point of destruction The crushing load is indicated by a graduated dial.

Laboratory Tests

8.26 In 1958, with the improvised testing machine described in the previous para, rubble masonry cubes of 0 9 m size were tested at Hirakud (India) and also at Denver (U.S.A.).

The Central Water and Power Commission entrusted the testing of masonry cubes of 0 9 metres to the U S. Bureau of Reclamation These were especially entrusted to the laboratories in Denver which are equipped with large scale testing machines for testing materials At the request of the Government of India, comprehensive investigations of rubble masonry were undertaken by the bureau under a technical assistance agreement. The following conclusions were drawn after detailed investigations :

The 28-day strengths of rubble masonry were approximately 80 to 90 per cent of the 90-day strengths. The compressive strength of a masonry cube of 0 90 m (1 : 3 cement to sand ratio) was 189 kgs per sq. cm for a 28-day test, whereas it was 235 kg. per sq. cm. for a 90-day test. Similarly, for the masonry with 1 cement : 4 sand, the strengths were 150 and 190 kg. 1 sq. cm. and for 1 . 5 mortar 143 and 160 kg./sq. cm. respectively.

The strength of rubble masonry made with 1 : 4 mortar was only slightly below that usually observed for mass concrete 1 : 2 : 4 mix

Masonry made with concrete was much stronger than masonry made with mortar, probably due to better bonding The strength of masonry with 25 mm size aggregate concrete, for 0.90 m masonry cube of 28 days in kg. per sq. cm. was 266 lbs as against 309 of 90 days. The results are tabulated below:

Compressive strength kg. per sq. cm. (Average)

Sl. No	Cement to sand ratio	0 9 m Masonry cubes	
		28 days kg. per sq cm	90 days kg per sq cm
1	1 : 3	189	235
2	1 : 4	150	190
3	1 : 5	143	160
4	With 25 mm. maximum g size concrete matrix	266	309

The above tests were carried out on 0.90 m rubble masonry cubes which are of maximum size that could be tested in 2 25 million kg. testing machine.

The rubble masonry cubes in U S A. were fabricated from local granite stones of a regular size and shape The mortar joints were uneven and included pockets that were to be filled with small stone pebbels of chips in order to reduce the mortar contents of the mass between 40 and 45 per cent, which is considered reasonable for this type of material in large construction The uniformity of these tests indicated that the material could be well controlled to provide a dependable strength as required by the designers.

It was also noted that the 90-day strengths were 16 per cent higher than the 28-day strengths. It was also recorded that the granite stone is much stronger than the 28 day masonry strength as shown by the following results of the experiments .

	Granite	Masonry in Mortar	Ratio
1. Compressive strength kg. per sq cm	2,150	157	14 7
2 Triaxial shear strength kg per sq cm	327	42	7 8
3. Tensile strength kg per sq.cm.	120	19	6 4
4 Section modulus (10^6 kg per sq.cm) at 70 kg per sq cm	9 7	2 1	4.6
5. Poisson's ratio (at 70 kg per sq cm)	0 14	0.12	1 1

The concrete strengths are generally 30 per cent greater at the end of the year than the value at the end of 28 days.

The summary of the tests conducted on masonry cubes in the laboratories in the U.S Bureau of Reclamation and at Hirakud are tabulated below (kg per sq cm)

Proportion of cement mortar used in masonry	Results obtained at Hirakud		Results obtained at U S B of Reclamation	
	28 days	90 days	28 days	90 days
1 : 3	170		189	235
1 : 4	150		150	190

True copies of the test reports of masonry conducted in Hirakud and in the U S are given in the table 8 1 at the end of this Chapter.

Revised Recommendations of the Committee

8 27 After the receipt of the laboratory tests from Hirakud and U S A., the committee on August, 14, 1958 proposed revolutionary changes in the technique of masonry construction The members proposed replacement of concrete in highly stressed zones with masonry 1 : 3 mortar On an analysis of the results of the tests, they found that the maximum principal stress of 30 kg. per sq cm. developed in the Nagarjunasagar dam could be taken safely with masonry built in 1 · 3 cement mortar with a factor of safety of 7 6 on 90-days strength This change by abandonment of concrete in the rear toe of the dam resulted in a saving of Rs four millions besides ensuring a higher factor of safety. The revised section of the dam is given in Fig. 17.

The members were of the view that the work must be of a high quality and that care must be taken in filling the joints with mortar and ensure good bond between stone and mortar. They recommended the appointment of an inspection squad for vibrating and for ensuring a good quality of masonry. One Superintendenting Engineer with sufficient field staff was recommended for the above work.

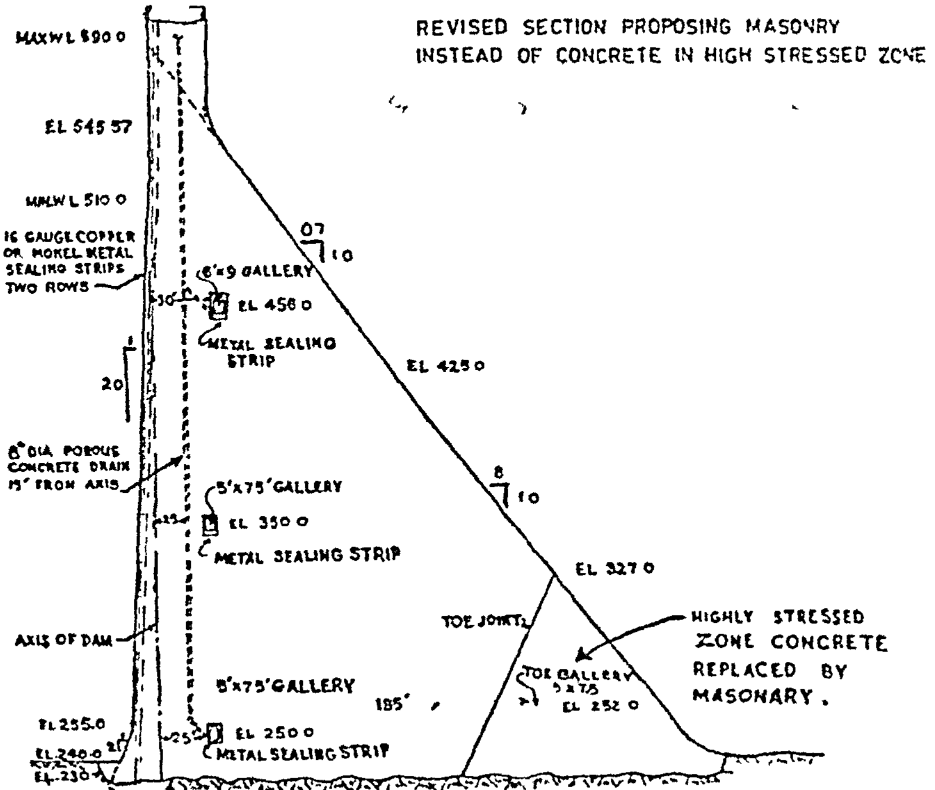
Advantages of Masonry vis-a-vis Concrete for Dams

8.28 Some important characteristics of masonry and concrete are summarised as under :

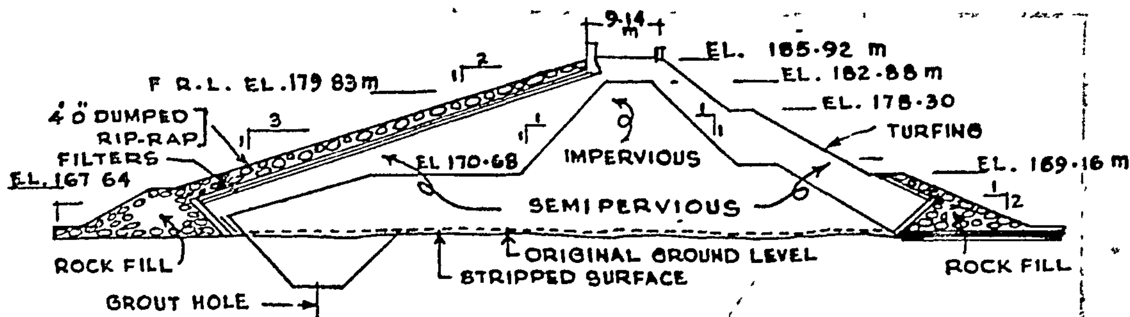
(i) *Strength*

Consequent on the elaborate experiments conducted on masonry in India and U S.A., it was proved, beyond doubt, that masonry could

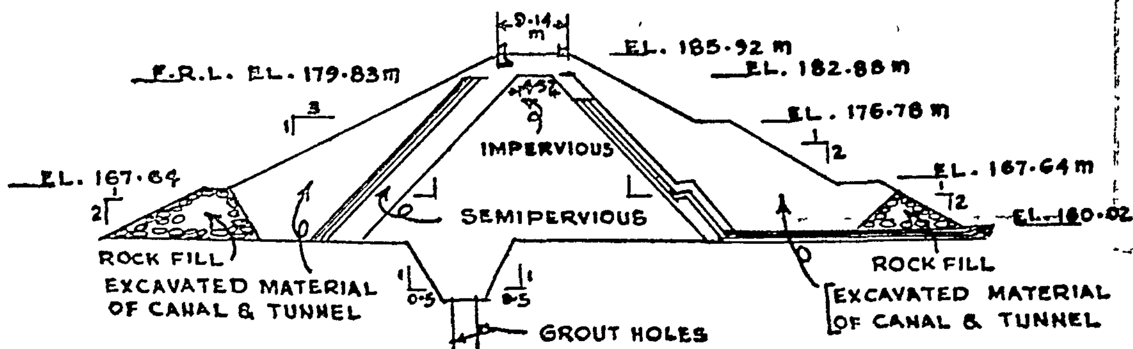
(*Para 8.27*) FIG. 17



(*Para 9.30*) Fig. 18



(*Para 9.31*) Fig. 19



withstand the required stress as concrete and that it could be proposed advantageously for construction works

(ii) *Cracking*

Cracking of the material should not occur in dams When a dam is built in concrete, due to excessive heat of hydration developed in the process of construction, cracks will form, unless artificial cooling by circulating water in pipes or precooling of aggregates or by both methods have been adopted systematically. This difficulty does not arise in the case of masonry as the heat of hydration slowly dissipates itself with masonry This is due to two reasons first the quantity of cement consumed in masonry is less and secondly, because masonry is built in layers of small thickness of about 0 3 m , whereas in concrete layers of 0 75 to 1.8 m are adopted for the convenience of shuttering, vibration and progress.

(iii) *Seepage*

A dam should be impermeable Due to leakage, the dam suffers on two accounts: loss of costly water stored and increased uplift pressure which reduces the strength of the structure and requires a large section to counter balance the uplift forces. The seepage results of the dams built in India with masonry, viz , Mettur dam, Tungabhadra and Nagarjunasagar, have shown that the masonry has a decisive advantage over concrete dams.

Seepage discharges recorded on March 17, 1963 in the galleries of the Nagarjunasagar, show that the actual seepage is only 2 2 per cent of the permissible. This establishes the advantage of a masonry dam with respect to seepage

(iv) *Minimum Machinery*

A concrete dam requires more machinery for batching, mixing, conveyance and laying in position, cooling etc compared to masonry. Particularly in underdeveloped countries, it would be difficult to import the required machinery at high cost involving foreign exchange.

(v) *Reduction in Shuttering Cost*

In a masonry structure, shuttering is not needed, and the stones are aligned with the help of templates In the case of concrete, elaborate shuttering arrangements are necessary. It increases cost. This will also involve delay, as the shuttering will have to be removed and refixed as the height of the dam increases.

(vi) *Reduction in Cement*

Cement is a scarce and costly commodity and has to be utilised with economy. Several dams suffer due to delay in procurement of the required quantity and it becomes difficult to catch up with the time schedule. It is, therefore, a definite advantage if cement is used less. In a masonry structure, the quantity of cement required is 45 per cent compared to that of concrete of the same strength with smaller aggregates.

(vii) *Employment Potential*

The adoption of masonry provides work for about four times the workers otherwise needed for concrete construction. In a country like India and elsewhere with a potential of man power and problems arising out of unemployment, conditions go in favour of choice for a masonry structure The Nagarjunasagar dam has employed nearly 45,000 workers continuously for a period of ten years.

(viii) *Speed of Construction*

It is sometimes claimed that construction is faster in concrete as compared to masonry. This is not always true. But, to some extent this could be true in the case of narrow gorges where dams are built and the supply of stones is mechanised. But in the case of gorges with adequate width, masonry has a definite edge over concrete. Masonry is also amenable for mechanisation to some extent, though not as much as concrete for speed. Concrete requires time for procurement of machinery and its installation. On the other hand, masonry could be started advantageously with less machinery. In the Nagarjunasagar dam, where there was adequate space for the construction of masonry, a stupendous speed of construction was achieved There was a record progress of 7236 cu. m. in a day which has no parallel in the history of construction of dams of the world.

(ix) *Increase in Length of Blocks*

The co-efficient of expansion of masonry is 0.35×10^{-5} as against 0.60×10^{-5} for concrete. So the construction joints in masonry need not be placed as close as in the case of concrete dams The joints in masonry at Nagarjunasagar were kept as much as 21 m to 27 m. and 37 m., in Mettur dam, whereas the joints were restricted from 15 to 18 m. in Bhakra dam which is a concrete structure

(x) *Cost*

Before building the Nagarjunasagar dam, comparative costs were worked out in detail for the masonry and concrete alternatives. The rate worked out for masonry was Rs 40 per cu m (1 : 4 red cement mortar),

whereas the rate of concrete was Rs 52. Thus the extra cost involved of equal strength concrete was 30 per cent

RESUME

8.29 In this chapter have been highlighted several important factors to determine the choice for masonry or concrete for dams. In summary, when compared with concrete of equal strength, a masonry structure requires less quantity of cement which is a scarce material. Reduction in quantity of cement and depth of layers in construction has a great bearing on the reduced heat of hydration Regarding seepage, the results of Nagarjunasagar and other dams in India have proved that masonry has a decisive advantage over concrete Further, masonry does not require shuttering arrangements. With the above background and with an added advantage of relief to unemployment and speed in construction, masonry construction has a definite preference over concrete for dams, specially in developing and under developed countries, where labour employment is a great problem. By building Nagarjunasagar dam in masonry, there was a saving of 25 per cent

As in the case of the Bhakra dam, where good stones are not available, the mighty structure has been raised in concrete utilising cobbles In such places, depending upon the availability of materials, machinery, *technology, speed in construction, and economy, the choice may be in* favour of either concrete, earth or a rock-fill dam.

It is, therefore, necessary to conduct greater research in various aspects of construction details regarding thinking on design criteria such as factor of safety which is 8 for masonry and 4 for concrete. After further tests if the factor of safety in masonry is reduced, there will be appreciable saving in the cost of future masonry dams. Evolution of improved tools for construction, mechanisation for transport and lifting, construction materials, quarrying and in other operations will lead to further economy, speed and efficiency in building masonry dams

TABLE 8.1

Test Reports of Masonry Blocks Fabricated and Tested at 4.5 Million Lb. capacity, Lakshmi Dungri Testing Station, for Concrete and Masonry.

Type of (1) Stone : Muria Dungri (Granite Gneiss)
(2) Sand : Mahanadi River (F.M. 2.6 to 2.8)
(3) Cement : Raipur Cement (Normal Portland Cement)

Sl No.	Test Block No.	Size of masonry Block	*Mix Details* Mix Ratio (Water : Cement : Sand)	Percentage Air entrained	Type of Masonry	Date of		Age (Months)	Compressive Strength in p.s.i.	
						Casting	Testing		Crack developed	Crushed
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1. ..	55	2½ ft. Cube	0.65 : 1 :3.0	Nil	Random Rubble	15-10-55	29-8-57	22½	..	4138
2. ..	43	do.	do.	Nil		11-10-55	27-9-57	23½	2210	4306
3 ..	24	do.	do.	Nil	do.	29-9-55	16-10-55	23½	2765	4480
4. ..	28	do.	do.	Nil	do.	1-10-55	17-10-55	24½	2613	4169
5. ..	39	do.	do.	Nil	do.	5-10-55	17-10-55	24½	2240	4231
6. ..	43	do.	do.	Nil	do.	7-10-55	18-10-57	24½	2210	4380
7. ..	25	do.	do.	Nil	do.	30-9-55	29-10-57	25	1369	4480
8. ..	40	do.	do.	Nil	do.	6-10-55	8-11-57	25	2240	4293

9.	..	56	do.	do	Nil	do.	15-10-55	30-10-57	24½	2240	4480
10	.	51	2 ft. Cube	do.	Nil	do	12-10-55	26-8-57	22½	.	4045
11	..	47	do.	do.	Nil	do.	10-10-55	21-10-57	24⅓	1944	4744
12	..	49	do.	do.	Nil	do.	12-10-55	21-12-57	24⅓	2139	4276
13.	.	45	do.	do	Nil	do.	7-10-55	23-10-57	24½	3111	4472
14.	..	10	2½ ft Cube	0.70 : 1 : 4 0	Nil	do.	22-9-55	30-8-57	23⅓	..	3970
15	.	9	do	do	Nil	do	22-9-55	10-9-57	23⅓	2864	4044
16	.	17	do.	0 75 : 1 : 4 0	Nil	do.	27-9-55	12-9-57	23½	..	4044
17.	.	7	do.	0.70 : 1 : 4 0	Nil	do	21-9-55	18-9-57	24	2988	4355
18.	.	12	do	do	Nil	do	23-9-55	29-9-57	24	3299	3795
19.	.	5	do.	do.	Nil	do.	20-9-55	19-9-57	24	3050	3982
20.	..	20	do	0 75 : 1 : 4 0	Nil	do	28-9-55	18-9-57	23⅔	.	3859
21.	.	22	2 ft Cube	do	Nil	do.	29-9-55	24-10-57	25	1944	2720
22.	..	18	3 ft Cube	do	Nil	do	27-9-55	11-4-57	23½	2490	3547
23.	.	13	2½ ft. Cube	0 70 : 1 : 4 0	Nil	do.	24-9-55	19-9-57	24	1991	3982

NOTE :—These tests were conducted in the F P S System, with the following C.G.S. equivalents .—

1 foot = 0.3018 m.

Pounds per square inch (p s i) = 0.0703 kg. per sq cm.

CHAPTER IX

LABORATORY AND QUALITY CONTROL

Quality is defined as the degree to which a construction meets the requirements of the soundness and stability of a structure A quality control organisation is an essential wing in the construction of hydraulic and other structures of complexity such as high dams The control organisation, established for such projects has also to advise on the speed and economy of the construction and provides inspection organisation, the means to accomplish the best construction at the lowest cost and aims at the specified standards of quality. It has to be an adjunct to design and construction and has also to effect economy and improvements in the standards. This has to be a comprehensive organisation and has to include field investigations, tests, research, formulation of specifications for materials and workmanship, inspection and methods for detection and prevention of flaws. Thus quality control has to cover the whole process of construction.

9.2 The quality control organisation has also to serve as a technical audit on departmental works. The organisation has to see that there is no excessive use of material and labour. Quality control officers have to check the strength and out-turn of labour employed departmentally to ensure that the labour is fully employed and that it is not employed on jobs which can be more economically done by contractors. The organisation has also to attend to physical verification of stores, conduct a careful review of the performance and sickness factor of the heavy and other machinery and suggest measures for improvements. The operations of the organisation do not in any way interfere with the powers or dilute the responsibilities of Officers-in-charge of construction. The organisation being directly under the Chief Engineer, all the defects and steps for improvements are brought to his immediate notice for proper control, and timely redress.

This organisation has also to check up stores by physical stock verification which is a continuous process Each item of stock is checked up once in six months Discrepancies are brought to the notice of the Chief Engineer and necessary action is taken against the lapses This keeps the organisation vigilant against misuse, pilferege and loss.

Magnitude of Work

9 3 This organisation played an essential role in the gigantic task of building the Nagarjunasagar dam which utilised colossal quantities of

materials and unprecedented manual labour for the construction. An account of important materials consumed in the Nagarjunasagar dam construction is given below

		M.cu metres	M. cft.
(i) Masonry in red cement mortar		4 80	171.00
(ii) Cement concrete	.	0 77	27.00
(iii) Earth fill	..	2 06	73.00
(iv) Rockfill and rip rap	.	0 29	10.20
(v) Filter materials	.	0.15	5 20
(vi) Sand	..	2 44	86.00
(vii) Rubble and aggregate	..	5 92	209 00
(viii) Steel	.	..	60,960 tonnes
(ix) Cement	..	..	11,40,000 tonnes
(x) Surkhi	.	..	2,00,000 tonnes

9.4 The above materials were mostly consumed in the working season from December to May for an average progress of 2832 cu m of masonry and 4248 cu m of earth work per day. Such a large consumption of materials required vigilance and care at every stage right from the selection of suitable materials from various sources to testing the materials in the laboratory, batching and mixing them in specified proportions, transport and placement in specified zones Trained quality control engineers worked hand in hand with the construction staff at various levels and ensured proper construction with requisite quality of the entire structure.

Organisation

9 5 A well equipped central laboratory was established with field laboratories at various work sites Inspection and control was headed by a Superintending Engineer, assisted by two Executive Engineers, 20 Assistant Engineers and 20 Junior Engineers/Supervisors/Research Assistants and 50 Laboratory Assistants The main laboratory building was designed and built by Mr. S. Bala Subramanyam who was the first Executive Engineer to organise the inspection and control organisation from the inception ; and he ably managed it for eight years

9.6 The following were the main functions of the organisation

(*a*) Investigation of raw materials and their testing in the laboratory and certifying their suitability

(*b*) Design of mixes of mortar and concrete for the specified strength and placement as per job requirements

(*c*) Batching of mortar and concrete at the plants and field control of the mix proportions

(*d*) Control of placement of masonry and concrete

(*e*) Placement of earth dam materials

(*f*) Permeability tests of masonry after placement

(*g*) Installation of instruments in the masonry and earth dams and keeping record of their observations.

Laboratory Tests

9 7 In general, the following tests were conducted in the laboratory of the Nagarjunasagar dam :

I. *Tests on Cement*

1. Chemical analysis
2. Fineness
   (*a*) Blaires Air permeability test
   (*b*) Sieve analysis on B S.S. 170 Mesh
3. Soundness (Le Chatelier's method)
4. Vicat-needle Test
   (*a*) Normal consistency
   (*b*) Initial setting time
   (*c*) Final setting time.
5. Compressive strength
   (*a*) After 3 day curing
   (*b*) After 7 day curing.
6. Tensile strength
   (*a*) After 3 day curing
   (*b*) After 7 day curing.

II. *Tests on Fine Aggregate (Natural Sand)*

1. Organic Impurities
   (*a*) Colour test
   (*b*) Treatment with hydrochloric acid
2. Deleterious Material
3. Fineness modulus
4. Unit weight (dry rodded)
5. Soundness test (with sodium sulphate)
6. Specific gravity.

III *Tests on Coarse Aggregate (Granite)*

1. Gradation analysis
2. Specific gravity
3. Unit weight (rodded)
4. Absorption
5. Crushing strength
6. Soundness tests (Sodium Sulphate)
7. Acid Test (with HCL, H_2SO_4)
8. Abrasion test (by loss Angles method)
9. Alkali aggregate reaction test

IV. *Tests on Mortar and Concrete*

1. Workability
2. Slump tests
3. Unit weight and yield
4. Bleeding test
5. Compressive strength
6. Mix performance test
7. Modulus of elasticity of masonry
8. Permeability of mortar
9. Determination of air entrainment
   (*a*) In mortar
   (*b*) In concrete
10. Determination of *in situ* densities and strength of concrete.

V. *Surkhi*

1. Mechanical analysis of soils
2. (*a*) Sieve analysis
   (*b*) Hydrometer analysis for soil
3. Chemical analysis of soil
4. Puzzolonic activity of surkhi
5. Determination of optimum temperature of calcination
6. Fitness test
   (*a*) Blaires air permeability method
   (*b*) Sieve analysis of B S 100 mesh.

VI. *Tests on Random Rubble*

1. Specific gravity
2. Absorption
3. Crushing strength
   (*a*) 1st crack
   (*b*) Ultimate strength
4. Acid Test

VII. *Tests on Water*

1. PH Value
2. Chemical analysis.

VIII *Tests on Soils*

1. Classification tests
   (*a*) Atterberg's Limit test
   (*b*) Mechanical analysis
2. Proctor's density test
3. Permeability test (falling head type)
4. Direct shear
5. Triaxial shear
6. Settlement tests.

Some of the important tests are described below :

9 8. Cement is the most important ingredient which was mostly procured from the Macherla Cement Factory that was specially installed at the initial stages of the project. The factory is situated 23 km. from the dam site. The cement was received from the factory both in bulk and also in bags. The bulk cement was carried through specially built railway wagons of 12.75 tonne capacity. For fast construction, the cement was also procured from the factories of Vijayawada, Shahabad and Panyam, which are situated more than 150 km from the dam site. For cement consignment, samples were taken and tested for chemical analysis, fineness, soundness, Vicat test for setting time, tensile and compressive strengths.

Surkhi

9 9 Quarries for surkhi were selected after conducting tests on soils for fineness, chemical analysis, optimum temperature of calcination and optimum percentage of replacement for maximum compressive strength when cast in combination with cement mortar.

Two quarries were found suitable . one in the Tiger valley and the other at Chalkurti. The temperature of calcination was controlled with pyrometric cores and the fineness of the surkhi after pulverization was controlled so as to conform to specification.

The following tests were conducted on sand .

(*a*) Specific gravity
(*b*) Silt contents and deleterious substance
(*c*) Organic impurities and fineness modulus.

The sand from Peddavagu was used in the initial stages and mostly from the Hallia river when the former got submerged in the rising waters of the reservoir

The following were the tests to ensure the suitability of rubble :

(*a*) Specific gravity

(*b*) Absorption and compressive strength

Granite stones were used from ground quarries of Nandi Konda and Bandala Karva

Aggregate

9.12 The tests conducted on aggregates were ·

Specific gravity
Absorption
Soundness
Crushing strength
Deleterious materials
Gradation and compressive strength when used in concrete.

The aggregate was procured from the granite stones Some quartizite stones which satisfied the above criteria were also tested and used. Only negligible quantities of quartzite metal of the required specification were available

Steel

9.13 Steel samples were taken from each consignment and they were tested for tensile strength, modulus of elasticity and percentage of elongation conforming to Indian Standards Specification.

In all about 1500 samples of sand, 50 samples of rubble and about 7000 samples of aggregate were tested

Tests at the Batching Plants

9 14 The quantity of raw materials being received at the batching plants was matched in the case of every receipt Materials found objectionable by field observations, were rejected at site and for doubtful cases samples were sent to the laboratory for tests and action was taken depending upon the test reports

The scales of weigh batching equipment as indicated by the dial pointers were verified at least once in a week and frequently whenever there was a doubt. The verification was doubly checked both by a standard weight and by actually reweighing the products issued by the plant scales.

The following field tests were conducted :

Gradation of metal
Fineness modulus
Fineness of surkhi
Weight of cement in bag
Slump tests for mortar and concrete
Sand moisture
Unit weight of mortar and cement
Bleeding tests
Mixer performance and wet mortar and concrete analysis.

Wet mortar and concrete analysis was done to ascertain the actual proportions of cement and surkhi and metal in the mixes. This served as an additional check.

Sampling, Casting and Testing Specimens

9.17 Samples were taken for every 282 cu m. of mortar or concrete and for every 140 cu m in the case of reinforced cement concrete Cylinders in the case of concrete and cubes in the case of mortar were cast and cured and subjected to tests at the end of 7 days, 28 days, 3 months, 6 months and one year. The tests were conducted in the central laboratory to see whether the designed strength was achieved and the permeability was within the limit specified

9 18 Care was taken and proper identification of vehicles carrying various types of mixes was kept to ensure that correct mix was utilized in the specified zone according to the strength required.

9 19 Any defects noticed either in the materials or in the performance of the batching plant, were immediately brought to the notice of the maintenance engineer and recorded in the plant inspection register. The defects were rectified then and there.

9 20 Depending upon the stresses, the sections of the dam were marked in different zones. In these zones the masonry of the dam was built with mixes of various strengths as described below :

Where the compressive stress exceeds, 21 87 kg. per sq. cm.

Where the stress is between 16 4 and 21 87 kg. per sq cm.

Where the stresses are less than 16.4 kg. per sq. cm.

Impervious mix (rich mix for the upstream 2.74 metres),

9.21 The strengths specified for the above zones were not less than 262 4 kg per sq cm, 174 9 kg per sq cm. and 131 2 kg/cm. respectively at an age of one year on 15 cm. cube. The designed mortar mixes were : (Proportion by weight)

Mix	*Water*	*Cement*	*Sand*	*Zone*
A	0.47	1 00	3 00	I & IV
B	0 60	1 00	3 91	II
C	0 70	1 00	4 72	III

Twenty per cent of cement (by weight) was replaced by surkhi in all the above mixes.

9.22 In respect of concrete, the following were the zones with specified strength and mixes used : (Proportion by weight)

Zone	Specified strength	Maximum size of aggregate	Mix adopted : Water : Cement : Sand
(*a*) Outer 1 8 m lining on the spillway face and spillway bucket	210 9 kg per sq cm	76 mm	0 49 : 1 00 : 4 62
(*b*) Trash rack structure above base and galleries	do	38 mm	0 49 : 1 00 : 5 62
(*c*) Around sluices, blockouts, elevator shafts, storage structures, walls and floors less than 280 mm thickness	210 9 Kg per sq cm	19 mm	0 50 : 1 00 : 4 99
(*d*) Spillway crest and piers .	281 Kg per sq cm	38 mm	0 42 : 1 00 : 4 62

The principal requirements of the design of the mix are ·

(*a*) Maximum density of the aggregate
(*b*) Workability
(*c*) High crushing strength and low permeability

9 24 Air entraining agent—Aerosin—a solution of soap consisting of rosin and caustic soda manufactured in the Nagarjunasagar Central Laboratory was used in mortar and concrete to improve the quality and the workability The dosage of aerosin was 0.1 litre per cu m. (1/16th gal. per 100 Cft)

The final measure of quality was determined by concrete specimens prepared at the batching plants The Nagarjunasagar dam specifications lay down that not more than 10 per cent samples tested shall have a compressive strength less than 80 per cent of the specified strength. Statistical analysis of the concrete and mortar, showing the mean values and standard deviation were prepared to have an idea of the control exercised at batching plants About 82,000 specimens of mortar and concrete were tested in this connection.

9 25 Moving average graphs were prepared to denote the strengths of concrete obtained on a time scale taking an average of five consecutive

test results at a time This gave indications when the process went out of control Thus, proper steps could be taken to restore the strengths.

Control at Site of Placement

9.26 The main construction works of importance could be divided into three parts: Masonry or concrete work on the main dam, construction of rolled fill earth dam on left flank and construction of rock-fill earth dam on the right flank.

Main Dam Constructions

9 27 The foundations of the masonry dam were inspected by the Geologists and the Superintending Engineer of Inspection and Control Circle before they were initially covered The masonry was built with red cement mortar. The average daily progress was 2832 cu m. (one lakh cft) of masonry and concrete and it touched a maximum of 7080 cum. (2 5 lakh cft) The alignments, levels and templates were verified at every stage before work was started. It was ensured that the area was cleaned with air-water jet and sufficient mortar was placed and stone was properly bedded and vibrated and small stones and spalls were wedged in between big stones. The excess mortar was removed at the same time, ensuring that mortar was filled in the interstices without leaving voids Masonry was constructed at the rate of only one course per day during the day shift of eight hours. In the intervening 16 hours, it was intensively and profusely cured to dissipate the heat of hydration before the next layer of masonry was laid.

Under unavoidable circumstances, such as emergencies to raise blocks quickly before floods, limited work was permitted with two layers being built on the same day. In this process, the second layer was built over the first before the latter started setting To achieve this, after building the first layer horizontally to 1 5 metre width, the second layer was started over it and then the first layer was continued. Placement of concrete was generally in lifts of 0.75 metres and a time of 24 hours was given between successive lifts to dissipate the heat of hydration Under emergency, lifts of 1.5 m. of concrete were poured and a time of 72 hours was given before the next layer was placed. Where it was not possible to allow the above timings, galvanized iron pipes of 38 mm dia. were laid in between lifts at 1.5 m. centre to centre for cooling with circulation water This became essential while raising block 41 emergently, against rising floods.

9.28 Special care was taken to ensure that the coarse rubble masonry for face work in the upstream 2.74 m. (9. ft) of masonry in rich mortar and the copper seal strips at contraction joints were put in

strict conformity with the specifications Concreting time was generally restricted to the cool hours of nights Alignment and level for the shuttering, proper tying of the specified reinforcement, laying of concrete, effective vibration and proper compaction were checked round the clock and ensured Concreting was done in lifts of 0 6 to 0 9 metres (2 to 3 feet) per day and intensively cured

Instrumentation

9 29 In a dam of this magnitude built for the first time in masonry, it was essential to measure the internal temperature, stress distribution, uplift pressure and joint openings in order to check the design assumptions and the behaviour of the structure during and after construction. This was accomplished by the electrical resistance method using instruments which were embedded in the body of the dam at the time of construction In this dam, resistance thermometers, stress meters, strain meters, joint meters and pore pressure cells were embedded and they were all of Carlson make The terminals of all the embedded instruments were taken to the nearest points in the gallery, which were approchable at all times of the year 26 strain meters, 68 resistance thermometers, 14 stress meters, 10 pore pressure cells and 8 joint meters had been embedded in the dam by the quality control organisation These have been described in detail in chapter VII

Rolled-fill Earth Dam on Left Flank

9 30 The total quantity of earh work involved in the left flank earth dam is 17 4 m cu m (613 m cft) Complete investigation of borrow areas was made to estimate the quantity of acceptable material The soils available could be broadly classified as clay soils, sandy loams (black and red) and gravels. Clay soils were used for filling all depressions, pockets, core layer of impervious zone and the cut off trenches, sandy loams in the semi-pervious casing section and gravels in the shell portion The earth dam was a zoned-rolled fill type, with rock toes provided on the upstream and downstream sides Graded filters and riprap were provided on the upstream The down stream slope was turfed and berms were provided at appropriate elevations.

The following procedure was adopted to ensure good quality on the earth dam :

The cleaning of foundations was checked and passed, the soil received from the approved quarry was tested for suitability and was spread in the area to an even thickness of 25 0 cm The layer was watered uniformly until optimum moisture content was obtained and then rolled by sheep foot rollers drawn by tractors and dozers After consolidation

cores were taken and tested for maximum dry density and then the area was passed if the maximum density was in permissible limits for pervious or impervious zone; the permissible limit being 98 per cent of Proctor density for the core and 97 per cent for the casing. In locations where it was not possible to do consolidation by machine rollers such as near edges of wing walls, filling of pockets and cut off trenches, hand tamping was resorted to and 95 per cent of the proctor density was adopted for passing the layer. Embankment registers were maintained at site to exhibit these details. For laying filters, the slope of the dam, the gradation of filter materials and the depth of layers were checked at every stage and passed for further work. In addition, *in situ* pemeability tests and laboratory shear tests were conducted Eighty thousand *in situ* density tests and 600 *in situ* permeability tests were done on both the earth dams.

Rock-fill Dam on Right Flank

9.31 Investigation of borrow areas on the right flank revealed that semi-pervious material like gravel soil was not available for the casing zone. Even the impervious soil was not available in sufficient and large quantities However, the canal excavated rock spoil was available very near the right earth dam Experiments were conducted and it was found that the rock spoil was sound and durable and was pervious when put into embankment So, to suit the material available, a smaller impervious core with the rock fill as casing zone with necessary filters upstream and downstream was proposed for the right flank earth dam.

9 32 For the right flank rockfill dam, besides the measures adopted for the control of quality on the left earth dam, the following specifications were ensured :

Clean fresh quartzite rock spoil varying in size from 0 15 to 0.46 m. (6″ to 18″) were used for the shell material Smaller stones were placed near the filters and bigger stones at the outer slopes The rock spoil was placed in 0 3 to 0.36 m (1′ to 1.2′) layers and dozed and compacted to obtain the designed density. To make this zone pervious, the compaction was regulated not to exceed the desirable limit, lest the layer should become impervious The density was often verified. Similarly *in situ* permeability tests for every 1 52 m. (5′) layer of rockfill embankment were carried out to ensure that the zone was pervious Control was exercised on the embedment of instruments to observe the behaviour of the dam such as stress, strain, pore water pressure, joint openings and temperature Observations on these instruments were recorded for correlation of results with the calculated values of stress, strain etc.

Seepage

9 33 'V' notches were installed in the galleries to measure the seepage through the porous concrete drains It was observed that the total seepage through these drains was only 1/40th of permissible values Percolation tests in holes, drilled in finished masonry, were conducted and the impermeability of masonry was ensured.

Research Work

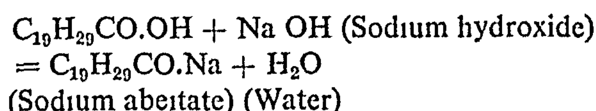
9 34 Aerosin is an air entraining agent In mixes of concrete and mortar, the necessity of entrainment of air, as a desirable component, was discovered in 1940. The air entraining agent is charged along with batch water for uniform distribution while mixing concrete With the introduction of the air entraining agent, innumerable microscopic air bubbles are generated in the process of mixing The air thus entrained and dispersed uniformly holds the fine and coarse aggregates of concrete in a more or less fluid medium and acts in bouying up the heavier particles during the process of vibration, reduces the settlement of heavier particles down and thus makes the concrete a homogeneous mass In addition, as it keeps the water cement ratio uniform at the surface and on sides, it resists the action of the flow of water with high velocity and prevents segregation.

9 35 There are many varieties of imported air entraining agents Avoiding foreign exchange, a special air entraining agent named Aerosin, was evolved for the first time in India at Hirakud Research Station In the early construction stages of Nagarjunasagar dam the aerosin developed in Hirakud was manufactured and used The ingredients of the Hirakud aerosin are Rosin of sodium or potassium grade, commercial caustic soda (NaOH), water and glycerine.

9 36 Experiments were conducted to find out whether the soap formed by the interaction of rosin and caustic soda could be directly dissolved in water without the necessity of reheating with glycerine and water. They revealed that the soap could be directly dissolved in excess of water without recourse to glycerine as a solvent medium The use of glycerine is to dissolve and to keep the soap molecules in suspension for a long period by its virtue of high viscosity. Though water is a solvent of this soap, it cannot keep soap molecules in suspension for a longer time as glycerine does Therefore, when water is being used as a solvent medium of this soap, it has to be used early after preparation.

The new type of aerosin developed at Nagarjunasagar is named Aerosin M The chemical composition of Aerosin M may be described as an alkaline solution which is prepared by dissolving a curdy precipi-

tate (Soap) in water. This precipitate (sodium abeitate) is obtained by treating rosin with strong alkali-sodium hydroxide. The chemical name for rosin is abeitic acid. Rosin is a residual organic solid matter-exudes of 'pines' species. It contains 90 per cent rosin acids (mainly abeitic acids). The chemical composition of abeitic acid is given in the formula as $C_{20}H_{30}O_2$ In the treatment of rosin with strong alkali, following is the chemical reaction when boiled :



$C_{19}H_{29}CO.OH + Na\,OH$ (Sodium hydroxide)
$= C_{19}H_{29}CO.Na + H_2O$
(Sodium abeitate) (Water)

The comparative costs of the air entraining agents as developed at Hirakud and Nagarjunasagar dam are tabulated below for showing the savings effected due to the experiments conducted at Nagarjunasagar dam .

Materials used		Hirakud Process			Nagarjunasagar process		
		Kgs	Lbs.	Rs	Kgs.	Lbs.	Rs
(i)	Rosin .	40.9	90	43.20	40.9	90	43 20
(ii)	Caustic soda ..	7.5	16.5	5 61	5 7	12 6	4.28
(iii)	Glycerine ..	8 2	18	35.28	—	—	—
(iv)	Coal ..	45 5	100	2.67	27.3	60	1 60
(v)	Labour charges ..			3.00			3.00
(vi)	Contingencies ..			6 24			6.24
	Total			96.00			58 32
	Yield (with water)	61 8	136		149	327	
	Cost			0.71/Lb.			0.18/Lb.

The filter is a costly item in the construction of earth dam. If the thickness of the filter can be reduced, considerable savings can be effected, in cost of earth dam especially when the source of the same is very far off.

To find out the minimum thickness of the sand filter for an earth dam which is below 30 m. in height, several experiments were conducted by varying the head of water pressure.

A special apparatus was devised to test the behaviour of the filter with different types of soils and with variable heads The analysis of the results of experiments revealed that placing a sand filter of less than

76 mm in thickness is of no avail, since the soil was found to be washed away through this slender thickness of filter. If the soils were of the lesser cohesion (plasticity index between 6 and 15) a 76 mm filter thickness with earth base material of plasticity index more than 15 is safe upto a vertical pressure of 3 4 kg per sq. cm.

The purposes of sand filters are: to arrest the movement of fine particles of earth along with the seepage water and to reduce the velocity of the seepage water through the dam.

Soil of good cohesion (plastiticity index between 15 and 25) is taken for comparative study with soils of lesser cohesion (plasticity index less than 15)

9.37 It is well known that if the soil is of good cohesion, the seepage will be especially less in magnitude which in turn reduces the strain on the filter.

Experiments conducted also determined the extent of the rigorous treatment necessary for filters in respect of an earth dam below 30 m. when the base soil is of cohesive type.

I. The observations of the test results are given below:
- (*a*) Compaction of soil 95% Proctors density.
- (*b*) Thickness of sand filter (3″ = 76 mm).
- (*c*) Head of water pressure applied over the soil 6 m (constant)

Permeability through different soils with more than 15 plasticity index (metres per year)	Permeability through different soils with less than 15 plasticity index (metres per year)
Nil	varies from 5.60 to 0.81

II.

(*a*) Compaction 95%	(*a*) Compaction 85%
(*b*) Plasticity index 21	(*b*) Plasticity index 11.
(*c*) D 15F/D15B = 1.00	(*c*) D15F/D15B = 1.00
(*d*) Sand filter 76 mm	(*d*) Sand filter 152 mm
(*e*) Pressure 12 m of water	(*e*) Pressure 12 m of water.

Note: (1) Suffix ' F ' is for the Filter material, and Suffix ' B ' is for the Base material.

(2) D 15 F/D 15 B = 1 00, implies that the average particle size of the fifteen per cent fine grade material of the filter is the same as fifteen per cent of the coarse grade material of the base, as per sieve analysis.

Co-effect of permeability (metres per year)	Sediment in percolated water	Co-effect of permeability	Sediment in percolated water
For different soils varies from 8.16 to 0 01	% is Nil	Nil	% is Nil

Note.—In the case of 152 mm. sand filter no sediment is washed out even though the D 15 F/D 15B was ·4, against the value 1.00 used conventionally. A filter of 76 mm. thickness was found safe for soils of plasticity Index 21, say between (15 to 25).

III		
	(*a*) Plasticity Index more than 15.	(*a*) Plasticity index less than 15.
	(*b*) 102 mm. soil cake.	(*b*) 102 mm. soil cake.
	(*c*) 76 mm. sand filter	(*c*) 152 mm. sand filter
	(*d*) Pressure 12 m of water.	(*d*) Pressure 12 m. of water.
	(*e*) 95% compaction (Proctor).	(*e*) 95% Proctors compaction.

Coefficient of permeability (metres per year)	Coefficient of permeability (metres per year)
For different soils varies from 0 60 to 0 17	For different soils varies from 0.17 to 0.01

IV Pressure 3 4 kg per sq cm. plasticity index 21, filter sand 76 mm with soil 102 mm.

Coefficient of permeability metre per year	Sediments observed in the percolated water
For different soils varies from 0.05 to 0 02	% is Nil

The following conclusions were drawn :

The thickness of the filter sand can be reduced to 76 mm. when the base soil is sufficiently cohesive (with a plastictiy index of more than 15 and less than 25).

For the above types of soil d15F/d15B can be safely kept at 40 against maximum of 100 as usually prescribed for earth dam below 30 m. in height.

It is worthwhile to conduct more experiments on soils of different plasticity index to arrive at the general requirements for different types of soil.

Hydraulic Research for Nagarjunasagar

9 38 Right from the start of the construction of the Nagarjunasagar dam, hydraulic research was conducted in the Andhra Pradesh Engineering Research Laboratories at Hyderabad The research included Hydraulic model studies, soil and foundation investigations, structural studies and testing of construction materials

9 39 Research on the spillway of the dam was the most important study. The two major features of the spillway which required model studies are the body-wall profile and the dissipating arrangements below the spillway. Extensive studies both on two and three dimensional models were conducted for this purpose. The special aspects studied in connection with the body-wall profile were the stability of the crest profile, pressure on the crest as well as the downstream glacis, and discharges for various depths of flow and various gate openings As regards the special arrangements below the spillway, preliminary studies were first made on several alternatives such as stilling basin, interacting jet dissipators and flip bucket These studies indicated that the deflector or trajectory type of flip bucket would be more economical than the other and would be quite safe in view of the sound rock formation existing in the vicinity Detailed studies were then taken up for designing the bucket As a result of these investigations a flip bucket of 21 34 m (70 ft) radius with other relevant specifications proved to be quite adequate and was adopted instead of the flip bucket of 27 43 m (90 ft.) radius recommended by the Central Water and Power Commission This design resulted in considerable savings in the cost of the structure

Hydraulic model studies were also conducted with regard to discharging capacity of the right canal head regulator, entrance curves, tested for negative pressures, energy dissipation and fixing the position of the right side training wall. From the results of model studies, necessary modifications were made in the construction features as per recommendations

9 40 The spillway structure was programmed to be completed over a number of years But, having finalised the ultimate shape of the spillway, the project authorities faced the problem of providing a suitable shape for the unfinished crest of the spillway at the commencement of

each monsoon so that no damage occurred to the glacis or the bucket portion, when the unfinished spillway was subjected to the highest flood. Model studies led to an arc of 9.14 m. (30 ft.) radius at the junction of the horizontal crest with the downstream glacis, suitable for all spillway discharges. The design was, therefore, recommended for adoption.

The unfinished crest of the spillway during various years of construction was built with random rubble with lean mortar of 1 cement and 8 sand finished with cement plaster 1 cement and 3 sand. After the floods this was dismantled every year.

Problems in the Operation of Gates

9.41 Problems in the operation of Gates have been explained in detail in Chapter VI. The model tests of these problems were conducted both at Poona and in the Laboratories of M A.N. of West Germany. It would be interesting to note that both the laboratories gave the same result.

RESUME

9.42 The quality control organisation thus exercised round the clock vigilance and care in establishing sound construction practices and contributed its share to the construction of the Nagarjunasagar dam

The hydraulic research laboratories at Hyderabad played an important role in solving several problems from time to time. Similarly, some difficult problems were also referred to the Hydraulic Research Laboratory at Poona They also effectively contributed to solving construction problems.

CHAPTER X

PROJECT COST

General

The cost of an irrigation and power project depends mainly on the site selected, the yield of the reservoir, adequacy of irrigable areas under command of the canal system, the availability of construction materials within economic reach, the cost of the areas going under submergence and the head available for the power generation The investigations have to be thorough under the guidance of an experienced engineer. The selection of the site requires the detailed investigations of various alternatives In Nagarjunasagar dam, all these conditions were excellently fulfilled.

At the site selected, good granite rocks were exposed in the bed where the spillway was located Good granite stone quarries were available within 7 to 11 km distance Good clay was available for the preparation of surkhi Quartzite sand of the required specification was available in plenty in river beds within 11 to 35 km A cement factory was built within 23 km of the dam site The site selected commanded an area of 1.21 million hectare for irrigation, and power could be produced at a head of 90 m Thus, the scheme was highly beneficial, unique in respect of availability of water, land to cultivate with excellent agriculturists owning good cattle The project was started with adequate field data and design.

Cost as per Original Estimates

10.2 The original estimates for a dam across the Krishna at Nandikonda site were prepared by the then Hyderabad Government and later on a joint scheme was finalised in 1954 by the Governments of Hyderabad and Andhra The joint scheme envisaged building a dam at the Nandikonda site with the full reservoir level at 179 83 metres and two canals, one on either side, to irrigate extensive arid lands where crops were failing very often for want of timely and adequate rains On completion, the scheme was estimated to irrigate 1 27 million hectares to produce 1 2 million tons of foodgrains annually In addition to irrigation, the scheme aimed at producing a firm power of 75 Megawatts at 0 6 load factor. A large amount of secondary power also could be available The power was to be produced where there was no hydel power nearby

10.3 The cost of the scheme as originally contemplated in 1954 amounted to Rs. 1,307.3 millions as per the details given below :

			Amount in million Rupees
1.	The dam with FRL 179.83 m	..	347.2
2.	Left bank canal (Hyderabad)	..	262 0
3.	Right bank canal (Andhra)	..	611.0
	Total	..	1,220.2
4.	Power cost with civil works, power plant and transmission	..	87.1
			1,307 3

10.4 The anticipated return on the irrigation scheme was 4.23 per cent. Including the power development, the return was estimated at 5 63 per cent. The period of construction was scheduled for nine years.

10.5 The design of the dam underwent many changes But the full reservoir level did not change from the level 179.83 m The design features as per actual construction have beeen fully explained in Chapter VII. It would be interesting to study the cost details of the dam estimated at Rs 347.2 millions, having gone upto Rs 730 millions with no change in the impounding capacity and the alignment of the dam remaining unaltered. The increase in the cost works out to 110%. The rise in the cost is mostly due to increase in the cost of materials during the period of construction and due to other causes which have been detailed in this Chapter.

10.6 The details of the original proposals are being given specially to appreciate various changes effected in the course of construction and also to assess the rise in the rate structure with the advance of time

10.7 The original cost of the dam estimated at Rs 347 2 millions comprises a spillway dam with crest at a level of 170.68 m. fitted with 20 crest gates of 18.29 m. width and 9.14 m. height. Adjacent to the spillway, on the left bank, the power dam was proposed which was flanked by non-overflow sections on the left. Both non-overflow sections on either side of the dam were flanked by composite dam sections, comprising a masonry wall on water face, backed with earthfill towards the air face. Towards the left flank, there is a saddle beyond the composite dam, where an earth dam was proposed.

10.8 The total length of the dam as per previous proposals was 4925 m. comprising of the following from the left flank :

Earth dam	..	2,225 m
Composite dam	..	530 m.
Non-overflow gravity dam	..	421 m.
Spillway		573 m
Non-overflow gravity dam	..	195 m
Composite dam	..	981 m.
Total	..	4,925 m

10.9 The spillway dam and the gravity sections were proposed to be built in masonry with red cement mortar. Apart from the composite dam facing with masonry, the subsidiary earth dam was to be with a maximum height of 20.5 m. on the left flank.

Revised Cost

10 10 In 1960 the estimate of the dam project was revised and sanctioned for Rs. 363 81 million. At the completion of the dam in 1970 a revised estimate was prepared for Rs. 730 million. The increased cost was due to increase in rates and due to some important changes from previous sanctioned proposals which are stated below :

The revised cost has also been compared with the original estimate in lakhs of Rupees (10 lakhs=one million)

Sub-head	Provision as per sanctioned estimate (in lakhs of Rupees)	Provision as per revised estimate (in lakhs of Rupees)
(1)	(2)	(3)
I WORKS		
Head Works ..		
A—Preliminaries	15 00	10 00
B—Land ::	120 00	146 00
C—Works	..	..
1. Dewatering and coffer dam and temporary river crossings etc,	33.00	95.00

Sub-head	Provision as per sanctioned estimate (in lakhs of Rupees)	Provision as per revised estimate (in lakhs of Rupees)
(1)	(2)	(3)
2. Spillway ..	1,731.50	4,403 00
3 Gravity dam .	843 60	
4 Composite dam including foundation for adjacent blocks .	44 00	345 00
5. Earth dam	29.00	
6. Ancillaries		
(a) Water supply including power for pumping water	.	20 00
(b) Power Supply . ..	..	70.00
(c) Trestle Bridge . .	..	31.00
(d) Haul Roads ..	..	70 00
(e) Workmen's compensation ..	..	2 00
(f) Labour amenities.	.	3.00
(g) Tunnel .	.	200.00
Total ..	2,816.10	5,395.00

D. *Regulators*

Sub-head	Provision as per sanctioned estimate (in lakhs of Rupees)	Provision as per revised estimate (in lakhs of Rupees)
1. River sluices . ..	10 20	..
2. (a) Construction sluice gates ..	..	5.00
(b) River sluice gates 10′ × 25′size 2 Nos including provision for emergency gates	..	..
(c) Gates for tunnel including embedded parts and emergency gates	..	68.00
3. Crest gates and hoists ..	15.00	175.00
4. Embedded metal works for gates in spillway	..	47 00
5. Right Canal Head Regulator gates.	..	33 00
6. Gantry Crane 1 No. .	.	14 00
Total ..	27 20	342 00

G. *Bridges*		
1. Bridge below dam . ..	37 00	38.00
2. Temporary river crossings ..	..	..
K. *Buildings*		
1. Camp buildings .. .	165.00	295.00
L *Boundary and Service Roads*		
1. Camp roads and service roads		
2. Approach roads	48 00	95 00
M. *Plantation*		
1. Avenues and Parks	5.00	35 00
O. *Miscellaneous*	115.00	350 00
P. *Maintenance* . . .	14.00	..
Q. *Railways*	50 00	65 00
Total I ..	3,277.30	6,615 00
Special T & P	60.00	60.00
Loss on Stock	5 00	6.00
II ESTABLISHMENT .. .	223 60	585.00
III T & P (ORDINARY)		
Purchases 15 00		
Repairs 7.20	22 20	12 00
V HYDRO ELECTRIC SCHEME		
Civil Works for embedment of penstocks of 8 Nos. of 14′ dia. with gates and foundations etc	50 00	221.00
Deduct		
Receipts and recoveries on Capital account	(–) 16.00	(–) 215 00
	3,622 10	7,284 00
Indirect Charges		
(A) Abatement of land revenue 6 00		
(B) Audit Charges 10 00	16 00	16 00
Total ..	3,638.10	7,300 00

The above cost is as per the revised estimate submitted to the Government in 1971.

Comparative Cost of Materials

10.11 A comparative cost of important building materials as in 1961-1967 is given under:—

NOTE: 100 cubic feet = 2 83 cubic metres

Sl. No.	Description of material	1961	1967	Percentage increase between Col. 3 and 4
(1)	(2)	(3)	(4)	(5)
		Rs.	Rs.	
1	Cement	63.98/MT	135.44/MT	139.80
2.	Sand including conveyance to bins.	25 00/100 cft	44.12/100 cft	76 60
3.	Face stone including removal of overburden	124.00/100 cft.	316.00/100 cft.	154.00
4	Rubble	23.50/100 cft.	40 83/100 cft.	73.72
5	Aggregate 3″ to 1½″	23.10/100 cft.	47.87/100 cft.	108.10
6.	½″ to ¾″	33/100 cft.	56.50/100 cft	72.22
7.	H S.D. Oil	0/44 lit.	0.87/lit.	97.12

Rates of Items

10.12 An abstract of rates of important items of Masonry and Concrete as in 1967 are given under :

S. No.		Per 100 cft.	Per cu. m.
		Rs.	Rs.
1.	Random rubble (R.R) Masonry in red cement mortar 1 : 3	163.64	57.80
2.	R.R. Masonry in red cement mortar 1 : 3 91	144.20	51.00
3.	Randum rubble masonry in red cement mortar 1 : 4.71	133.42	47.10
4	Face stone masonry in red cement mortar 1 : 3 71	329.95	116.16
5.	Face stone masonry in red cement mortar 1 : 3 91	310.51	109 70
6.	Face stone masonry in red cement mortar 1 : 4.71	299 73	105.50
7.	All type concrete with Surkhi using 6″ maximum size of aggregate	212.65	74.85
8.	A2 type concrete with Surkhi using 3″ max. size of aggregate	221.83	78.40

		Rs.	Rs.
9	A2 type concrete without Surkhi using 3″ max size of aggregate	234.49	82.85
10	B1 type concrete without Surkhi using 3″ max size of aggregate	233 83	82.62
11.	B1 type concrete without Surkhi using 3″ max size of aggregate	245.77	86.85
12	B2 type concrete using 1½″ max size of aggregate	266.08	94.00
13	B3 type concrete using ¾″ max. size of aggregate	299 01	105 65
14.	B2 type Plum concrete using 6″ to 8″ plums	248 74	87.90

Data

10 13 Data for random rubble masonry and face stone masonry are shown under as per costing of September, 1967 .

(I) *Data for Random Rubble Masonry in Red Cement Mortar (RCM)* 1 : 3

		Per 100 cu.ft.
		Rs
1	Cost of rubble and laying of masonry	51.69
2	Cost of sand	11.61
3	Cost of cement	79 15
4	Cost of surkhi .	4 10
5	Manufacture of mortar .	4 02
6	Transportation of mortar	4.24
7	Cleaning, curing slurry	2 66
8	Aerosine .	0 17
9	Miscellaneous, such as increase in rates for materials and labour after 9/67 in stock, unadjusted stock, suspense etc	6 00
	Rate per 100 cft. .	163 64
	Rate per cu m	57.80

(II) *Data for Random Rubble Masonry in Red Cement Mortar* 1 : 4.71

The rate of random rubble masonry in RCM 1 : 4.71 is derived from the rate of random rubble masonry in RCM 1 : 3 less the cost in the difference in quantity of cement and surkhi.

Cement	= 0 36 × Rs 79 15	= Rs. 28.80
Surkhi	= 0.36 × Rs 4 10	= Rs. 1 42
	Total ..	30 22

The rate for random rubble masonry in RCM 1 : 4.71 is	Rs	163.64
Less difference in Cost of Cement and Surkhi	Rs	30.22
Rate per 100 cft.		133.42
Rate per cu.m. =	Rs.	47.10

(III) *Data for Random Rubble Masonry in RCM*: 1 : 3 91

The rate of random rubble masonry in RCM 1 : 3 91 is derived from the rate of random rubble masonry in RCM 1 : 3 less the cost in the difference in quantity of cement and surkhi

		Rs.
Cement = 0.23 × Rs. 79.15	=	18 47
Surkhi = 0.23 × Rs. 4.10	=	0.97
		19.44

The rate for random rubble masonry in RCM 1 : 3.91 is	Rs	163.64
Minus difference in cost of cement and surkhi	Rs	19.44
Rate per 100 cft. =	Rs.	144.20
Rate per cu m. =	Rs.	51.00

(IV) *Face Stone Masonry in Red Cement Mortar* 1 : 3

Average cost of face stone including laying

$$\text{is } \frac{175 + 261}{2} = \text{Rs } 218.00/\text{unit}$$

Cost of random rubble masonry in red cement mortar 1 : 3 is Rs. 163 64/unit of 100 cft.

Add, difference in cost of face stone and rubble to arrive at cost of face stone masonry in Red Cement mortar 1 : 3.

Rs. 218.00 — 51.69 = 166.31

i.e., 163.64 + 166.31 = Rs 329.95/unit of 100 cft.

Rate per cu.m. = Rs. 101.65

(V) *Face Stone Masonry in Red Cement Mortar* 1 : 3.91

The cost of random rubble masonry in red cement mortar is Rs 144 20.

Add, difference in cost between face stone and rubble to derive the data for face stone masonry in Red Cement Mortar 1 · 3 91

Rs. 218.00 — 51 69 = 166 31
144 20 + 166 31 = Rs 310.51

The rate per 100 cft for face stone masonry in red cement mortar 1 : 3.91 is Rs. 310.51

Rate per cu.m = Rs 109.70

(VI) *For Face Stone Masonry in* 1 · 4.71—*Red Cement Mortar*

The cost of random rubble masonry in red cement mortar 1 : 4.71 is Rs 133 42/unit

Add difference in cost between face stone and rubble to derive the data for face stone masonry in Red Cement Mortar 1 · 4 71

Rs 218 00 — 51 69 = 166 31

Rs 133 42 + 166.31 = 299.73

The rate per 100 cft. for Face Stone Masonry in RCM 1 4 71 in Rs 299.73.

= Rs 105 5 per cu m.

Costing for Rubble Supply

10 14 Cost of rubble is worked out as follows .

Lead of the stone quarry from the dam rubble dump 8 miles = 13 km

		Rs
Lorry hire charges per mile ..		1 39
Cost of drill rod of 5 feet length ..		77
Average life of drill rod .. .	450 rft	
Yield of useful rubble per ft. of drilling	15 cft	
Cost per lb. of gelatine .. .		2.44
Yield of Rubble per lb of gelatine	110 cft	
Electric detonators required for one lb of gelatine		2.50
Drilling out-turn per shift	130 rft	
Drill rods required for 100 cft of rubble.	1.5 Nos.	

RATE FOR 100 CFT. RUBBLE

	Rs	Rs.
(i) *Materials*		
(a) Drill rods	1.16	
(b) Gelatine . . .	2.22	
(c) Electric detonators	1.14	
	4.52	4.52
(ii) *Machinery—(Hire Charges)*		
(a) Compressor	1.74	
(b) Jack hammer	0.20	
	1 94	1 94
Total ..		6.46
(iii) *Labour—(Charges)*		
(a) Splitting and loading	9.75	
(b) Removal of quarry rubbish and spalls.	0.73	
(c) Rehandling of rubble .. .	1.72	
(d) Supervision Charges . .	2.56	
	14 76	14.76
(iv) Transport Charges for 8 mile lead		
$= \frac{2 \times 8 \times 1\ 39}{1\ 50}$		
(A lorry could carry 150 cft or 1.50 units)		14.73
Total ..		35.95
Contingent expenditure Lumpsum.		1.05
Total .		37 00
Deduct for spalls used for breaking metal.		1.00
Cost per 100 cft. of rubble ..		36.00
Cost per cubic metre		12 60

Cost of Mortar

10 15 Following are the cost details per cubic metre of mortar .

Year of manufacture Feb 1966

Proportion of mortar; one Cement and 3.91 sand

DATA FOR 100 CFT MORTAR

One cum. = 35.52 cu. ft.

	Rs.	Rs
(i) *Cost of sand*		
(*a*) Cost of sand delivered from Halia quarry from 12 miles 104 cft. @ Rs 42 per 100 cft.	43.68	
(*b*) Dosing charges for heaping the sand over the conveyor tunnel.	0 59	
	44 27	44 27
(ii) *Conveyance of sand from sand dump to Batching Plant*		
(*a*) Depreciation of belt conveyors	1.22	
(*b*) Major repairs for belt conveyors	0 26	
(*c*) Maintenance charges	0 27	
	1 75	1.75
(iii) *Cement*		
(*a*) Cost of 0 9765 metric ton @ Rs. 167 18 per metric ton.	163 25	
(*b*) Conveyance and feeding charges .	4 53	
	167 78	167 78
(iv) *Lifting of cement to Batching Plants*		
(*a*) Depreciation of screw conveyor and lifting device	0.66	
(*b*) Major repairs ..	0 92	
(*c*) Maintenance charges .	0.17	
	1 75	1.75

(v) *Surkhi*

	Rs.	Rs.
Cost of 0 23114 m.t. @ Rs. 31.80 per m.t.	7.36	
Conveyance and feeding charges ..	0.96	
	8.32	8.32
(vi) Aerosin	0.10	0.10

(vii) *Mixing charges*

Depreciation of batching plant .	3.60	
Major repairs	1.34	
Maintenance charges	2.56	
	7.50	7.50
Total cost per 100 cft. of mortar		231.47
Cost of mortar per cubic metre .		81.70

Costing of Random Rubble Masonry

10.16 Following is the unit cost of random rubble masonry per cubic metre in 1963 : Proportion of mortar: one cement and 3.91 sand.

DATA FOR 100 CFT. OF MASONRY

(i) *Cost of rubble*

100 cft. of rubble at the quarry as per data including transport	36.00	36.00

(ii) *Mortar*

Mortar in 100 cft. of masonry ..	45 cft.	
Wastage at batching plant	0.5 cft.	
Wastage in Carriage and sticking to the containers.	1.25 cft.	
Wastage at the dumping platform ..	0.65	
Wastage in carriage to the site manually.	0.60	
Total wastage ..	3.00 cft.	
Total mortar required	48.00 cft.	
Cost per 100 cft.	231.47	

$\frac{231.47 \times 48}{100}$ = cost of 48 cft. mortar. 111.10

(iii) *Building Charges*

		Rs.	Rs.
1/2 mason @ Rs 6 per day	..	3.00	
1/2 packer @ Rs. 3 per day	..	1.50	
4 mortar carriers @ Rs 1 50 per day	.	6.00	
2 spall carriers @ Rs 1.50 per day	..	3.00	
1/2 stone lifters (Jawalis) 4 persons each @ Rs 4 × 4 × 1/2	..	8.00	21.50

(iv) *Cleaning, Curing and Slurry*

(*a*) Cleaning charges	..	..	2.30	
(*b*) Curing charges	..	..	3.00	
(*c*) Cement slurry ..	..	..	3.00	
			8 30	8 30
Cost per 100 cft of masonry		..		176 90
Cost per cu.m of masonry		..		62.00

The above cost includes lifting materials up to a height of 10 feet and a lead of 150 feet. It does not include the contractors profits and the following ancillaries .

Ancillaries per 100 *cft. of masonry*

			Rs
(*a*) Maintenance of Township labour and materials.			3.00
(*b*) Workmen's compensation		..	0 75
(*c*) Lighting charges	..	..	0.60
(*d*) Water supply	..	..	1.50
(*e*) Ordinary tools and plant		..	0.75
(*f*) Service roads	..	..	0 75
(*g*) Laboratory charges	..	..	0.75
(*h*) Supervision ..	..	..	2.40
Total ancillaries per 100 cft of masonry.			10.50
Total ancillaries per cu.m. of masonry.			3.67

Cost of Face Masonry (1 . 3.9 proportion mortar)

10 17 The details of cost of masonry are worked out below:

		Rs.	Rs.
(i) Cost of face stones for 100 cft. of masonry of 1′-6″ average width.			228.00
(ii) *Mortar*			
Proportion: one cement and 3 sand.			
Cost of mortar of 1 · 3 9 proportion for 100 cft	..	231 47	
Add extra cement 6.16 bags at Rs. 7 per bag	..	43 12	
Total	..	274.59	
Mortar cost for 40 cft. @ Rs. 274.59 (including wastages) per 100 cft.			110.00
(iii) *Building Charges*			
1 mason special @ Rs. 8 per day	.	8.00	
1 Packer @ Rs. 3 per day	..	3 00	
1 Stone dresser for adjustments @ Rs. 5 per day.	.	5 00	
4 mortar carriers @ Rs. 1 50 per day	..	6.00	
2 spall carriers @ Rs. 1.50 per day	.	3.00	
3/4 stone lifters (Jawalis) 4 persons each @ Rs. 4 × 4 × ¾	..	12.00	
Total	.	37 00	37.00
(i) *Cleaning, Curing and Slurry.*			
(*a*) Cleaning charges	..	2 30	
(*b*) Curing charges	..	3.00	
(*c*) Cement slurry	..	3.00	
Total	.	8.30	8.30
Total cost of 100 cft.	.		383.30
Total cost of one cu. metre	.		145.50

Cost of concrete

10.18 The cost of 1½″ concrete (Strength 5000 lbs. per sq inch) is as follows :

	Rs.	Rs.
(i) *aggregate*		
(*a*) 1½″ metal 47 cft. @ Rs. 45 per 100 cft	21.15	
(*b*) 3/4″ metal 43 cft. @ Rs. 70 .	30 10	
(*c*) Dozing charges . ..	0.50	
(*d*) Screening	6 00	
(*e*) Contingencies . ..	0 30	
Total .	58 05	58.05
(ii) *Sand*		
(*a*) Cost of sand delivered from Halia quarry from 22 miles 48 cft. @ Rs. 42 per 100 cft.	20.16	
(*b*) Dozing charges for heaping the sand over the conveyor tunnel	0.40	
Total ..	20.56	20 56
(iii) *Conveyance*		
(*a*) Belt Conveyor Depreciation	1 22	
(*b*) Major Repairs .	0 26	
(*c*) Contingent charges.. .	0 22	
Total ..	2.70	2.70
(iv) *Cement*		
(*a*) 1.208 Metric tons @ Rs 169 90 per m t.	205 22	
(*b*) Conveyance .	5.41	
(*c*) Depreciation of the machinery for lifting	0 65	
(*d*) Major repairs .. .	0 32	
(*e*) Contingent expenditure .	0 40	
Total ..	212 00	212.00
(v) *Aerosin* ..	0 12	0.12
(vi) *Mixing Charges*		
Depreciation	3 60	
Major repairs.	1.34	
Contingent charges . ..	3.06	
	8 00	8.00
Total cost for 100 cft.		301 43
Total cost for 1 cu. metre ..	.	114:50

Conveyance of Concrete by Belt Conveyors

10.19 Following is the data for the conveyance of concrete or mortar through belt conveyors—lead 1460 feet or 445 metres.

Cost of Belt Conveyor Equipment :

	Rs.
460 rft. 30″ wide .	2 37 lakhs.
500 rft 30″ wide . ..	3 20 "
500 rft 36″ wide	3 68 "
Erection charges for 30″ Conveyor	2.39 "
Erection charges for 36″ Conveyor	1.92 "
Total ..	13.56 lakhs.

Cost of Maintenance :

1967-68	Rs 2,45,000
1968-69	Rs 1,80,000
Total ..	Rs. 4,25,000

Quantity of concrete laid during the above period. (unit of 100 cft.)	= 20,565 units
Mortar	= 1,400 "
Total ..	21,965 units.
Say ..	22,000 units.
Taking 25% of the cost of Belt conveyor equipment together with erection charges = $\frac{13.56}{4}$	= 3 39 lakhs.
Full value of Maintenance charges ..	= 4 25 "
Total ..	7.64 lakhs.
Total concrete conveyed including mortar etc.	22,000 units.

Therefore, cost of conveyance of concrete, per unit $= \frac{7,64,000}{22,000}$

= Rs 34.73

Say Rs. 35 per 100 cft.

or

Rs. 12.36 per cu.m.

Labour Wages

10.20 The wages of various categories of labour employed on daily wages for eight hour working are given in the Table 10.1, at the end of the chapter. Work done for extra hours was paid as overtime. For

casual labour, payment was not made on Sundays and holidays, whereas labour employed continuously was paid on Sundays and holidays.

Details of Earth Moving Equipment

10.21 We now give details of costs of the equipment rates and analysis of rates of some important items of work In a river valley project like Nagarjunasagar where big perennial rivers have to be harnessed, heavy earth moving machinery is a 'must'. The river diversion works of the Nagarjunasagar dam started with the purchase of new earth moving machinery consisting of two bulldozers, five scrapers and a grader Later, some more new equipment was purchased from time to time and also old surplus machinery from completed projects such as Hirakud and Tungabhadra The total cost of the equipment was Rs. 20 million.

10.22 The following is a list of the machinery which was procured:

	Quantity in Nos	Cost per unit in Rs	Condition
I. *Dozers*			
(*a*) Cat. D 8 dozer 14 A series	4	130,000	New
(*b*) I H T D. 24 dozer ..	3		,,
(*c*) A C.H.D 16 dozer ..	1		,,
(*d*) Cat. D 8 Dozer H Series	2		,,
(*e*) Cat 819 C tyred dozers ..	2	300,000	,,
II. *Motorised scrapers*			
(*a*) Cat. DW—15 scraper (12-14 cu. yds) 9 2-10 5 cu m.	2	145,000	,,
(*b*) A C. Scraper T. 3200 9.2-10 5 cu. m (12-14 cu. yds) .	2		,,
(*c*) Let. 'C' Scraper ..	4		,,
(*d*) Euclid scraper model S12	1		,,
(*e*) Euclid scraper model B-6 FDT ..	6		,,
III. *Excavators*			
(*a*) P & H excavator with draglines 955 A 1 92 cu m. (2½ cu. yds) .	4	500,000	,,

(*b*) Marian shovel 93 M ..	1		New
(*c*) North-West shovel 0.58 cu.m. (3/4 cu. yds.) ..	1		Old
IV. *Rear Dumpers*			
(*a*) Euclid rear dumpers B ITD 10 to 13.90 cu. m. (13 to 18 cu. yds.) ..	11	212,000	New
(*b*) Euclid rear dumpers B 3 FD 7.7 to 9.2 cu. m (10 to 12 cu. yds.) ..	5	110,000	Old
(*c*) Let 'D' rear dumpers 4.6 to 6.0 cu m.) (6 to 7½ cu yds) ..	7	100,000	New
(*d*) Let 'C' rear dumpers 10.5 to 12.6 cu. m. (14 to 16.4 cu. yds.) ..	3	212,000	,,
(*e*) Kohiring dumpers 3.5 cu. m. (4½ cu. yds.) .	7		Old
(*f*) Mogurt dumpers 3 5 cu. m. (4½ cu yds.) ..	7		,,
V. *Bottom dumpers*			
(*a*) Cat DE 20, 6.2 cu. m. (8 cu. yds) ..	12		,,
(*b*) Euclid B 7 FTD 6.2 cu. m. (8 Cu yds.)	5	240,000	,,
(*c*) Cat DW 15; 7.7 to 9.2 cu. m. (10 to 12 cu. yds) .	1		New
(*d*) Cat 619 C. 13.9 to 15.4 cu m (18 to 20 cu yds.)	8		,,
VI. *Tractor Crawlers*			
(*a*) Cat D. 6 .	2		,,
(*b*) A.C HD 6 .	3		Old
(*c*) I.H. BTD 6 .	1		,,
(*d*) Fowler tractors 60 H.P, ..	6		,,

VII *Tractors Pneumatic tyres*			
(*a*) Super 8 MD Formal tractors .	6		New
(*b*) A.C tractors with P. 3 Engine .	4		,,
(*c*) Escort 37	2		,,
(*d*) D W 20 Tractor	1		,,
VIII *Motorised Graders*			
(*a*) Cat grader 100 H P	2	150,000	New
(*b*) Gallion grader .	2		,,
IX *Loaders*			
(*a*) Eimco rear end loaders 1 9 cu. m (2½ cu yds)	5		New
(*b*) Eimco front end loaders 1 9 cu m (2½ cu yds)	5		,,
X. *Cranes*			
(*a*) Loraine crane 5 ton Capacity 6.50 m (20 ft) radius	1		Old
(*b*) Coles crane 10 ton capacity	2		New
(*c*) Lima crane 10 ton capacity 6.5 m (20 ft.) radius	6		,,
XI. *Consolidation Equipment*			
(*a*) Diesel road rollers 10 ton capacity	15	70	New
(*b*) Sheep foot rollers 8 ton capacity	29		,,
(*c*) Sheep foot rollers 30 ton capacity	1		,,

The machinery was procured at different stages of construction when the costs went on rising The available figures are shown to indicate the general cost of the equipment required to tackle a work of this magnitude

Consolidation Charges

10 23 The consolidation charges with sheep foot rollers worked out to Rs. 3 43 per cu m (Rs 98 per unit of 1000 cft.) on the left earth dam and Rs. 2 45 per cu m. (Rs 70 per unit of 1000 cft) on the Right Earth Dam The difference in rate is mostly due to nature of soils used.

Miscellaneous Equipment

10 24 Apart from the above earth moving machinery, different types of equipment for batching plants, lifting and conveyance of materials were required The cost involved in all the mechanical equipment was about Rs. 50 million. The cost of other mechanical equipment is given under:

	No.	Cost per unit in Rs.	Condition
I. *Cranes for Lifting Materials*			
(*a*) Fowler cranes 5 ton capacity ..	2	47,000	New
(*b*) Lima cranes 25 tons capacity ..	6	280,000	,,
(*c*) Monotower cranes 8 ton capacity 28 2 m. (92.5 ft) radius ..	19	310,000	
(*d*) Clyde cranes 8 tons capacity 3.3 m. (10 ft.) radius	2	200,000	Old
(*e*) Washington cranes 10 ton capacity 29.5 m. (90 ft.) radius ..	2	250,000	,,
II. *Lorries*			
(*a*) Leyland 10 ton capacity ..	158	60,000	New
(*b*) Tata Mercedes Benz tippers and lorries of 8 ton capacity ..	30	55,000	,,
(*c*) Dodge tippers and lorries 5 ton capacity ..	25	45,000	,,
III. *Trailers*			
(*a*) Oskosh 20 ton capacity ..	1	350,000	,,
(*b*) Mack 20 ton capacity ..	1	350,000	,,
IV. *Batching Plants*			
(*a*) Winget 4 mixers of 23 cu. m. (3 cu yds.) capacity complete with weigh batching equipment, electrically controlled, storage bins, trestles, belt conveyors, etc. ..	1	2,000,000	Old
(*b*) Blaw-knox batching plant consisting of 2 mixers of 0.77 cu. m. (one cu. yd.) capacity complete with weigh batching equipment, storage bins etc.	4	500,000	,,

Hire charges of Machinery

-- 10.25 The hire charges for different classes of machinery have been worked out broadly on the following lines :

The life of fast moving machinery such as scrapers, dozers, and dumpers was assessed at 10,000 hours, whereas the life of stationary and slow moving machinery such as shovels, loaders, sheep foot rollers and batching plants was fixed at 15,000 to 20,000 hours depending upon the moving components involved in the machine.

The tyres and tubes were assumed to depreciate after a running of 40,000 km This aspect assumes that the roads are maintained in good condition.

Repairs and maintenance charges were computed at 100 per cent on the depreciation of the machinery and 10 per cent on the tyres and tubes

Based on the above assumptions, some hire charges of the important machinery including the cost of fuel, lubricants and labour charges computed on an hourly basis are given below .

	Cost in Rs	Hire charges per hour Rs
D 8 dozer 191 H.P. .	1,42,000	56.54
T D. 24 Dozer 190 H P. .	1,10,000	50 08
Let scraper 208 H.P.	1,51,000	71.25
Euclid scraper 250 HP	1,41,000	76 24
Gallion grader 125 HP ..	66,000	35 68
Euclid rear end dumper 10 8 cu m. capacity (14 cu yds) 190 HP .	1,34,000	65.20
Let. D Rear end dumper 138 H.P. 5.6 cu.m. (7½ cu yds.)	99,000	49.81
D W. 20 Bottom dumper 300 H P. 10 8 cu. m (14 cu. yds)	1,53,000	90.51
P.H Shovel 210 H P. 1.9 cu. m. (2½ cu yds) .	4,20,000	86.72
Marian Shovel 300 H.P. 1.9 cu.m (2½ cu yds) .	5,97,000	122.20
Coles crane 40 H P 3 8 cu.m. (5 ton capacity) .	1,23,000	33 96
Loraine crane 150 H P. (10 ton capacity)	50,000	31 80
Formal tractor 50.5 H P .	16,000	13.63
Eimco front end loader 205 H.P. 1 9 cu m (2½ cu. yds)	1,61,000	51.58

Rate for Conveyance of Soils

10.26 The following are the data for excavation and conveyance of impervious soils for the Left Earth Dam by heavy machinery :

Lead—4 miles (6.5 km) or 8 miles (13 km.) miles round trip.

Machinery combination : Shovel with dumpers.

Capacity of (P & H) Shovel ..	$2\frac{1}{2}$ cu. yds.
Euclid rear end dumpers .	14 cu. yds.
Job efficiency	65%
Swell factor .	80%
Cycle time for loading ..	30 seconds
Speed of dumpers ..	15 miles per hour

Quantity of earth that a shovel can load per hour $\frac{2\ 5}{30} \times 3600 \times \frac{65}{100} \times \frac{80}{100}$

$= 156$ cu. yds.

$= 4212$ cft

Capacity of dumper allowing Swell factor .. $14 \times 0.8 = 11.2$ cu.yds.

$= 302$ cft.

Loading time .. $\frac{\text{Capacity of dumper}}{\text{Shovel output}}$

$= \frac{302}{4212}$ hours.

$= \frac{302}{4212} \times 60 = 4\frac{1}{5}$ min.

$=$ Say 4 min.

Travel Time .. $= \frac{\text{Round Trip distance}}{\text{Speed}}$

$= 8/15$ hours

$= \frac{8}{15} \times 60 = 32$ minutes

Time required for loading, spotting and unloading $= 6.5$ minutes.

Total time $= 32 + 6.5 = 38\ 5$ minutes Say 40 m.

Number of dumpers a shovel can feed

$= \frac{40 \text{ min}}{4 \text{ min}} = 10$

Number of trips that a dumper can make in a shift of 8 hours $\frac{8 \times 60}{40} = 12$

Deduct for tea break and fuelling and other contingencies @ 20% $= 2$

Effective number of trips $= 10$

Hence machinery combination works out to 10 dumpers for a shovel

Adopting a job efficiency of 65%, progress that can be achieved with a unit of one shovel and ten dumpers

$$= 10 \times 10 \times 302 \times \frac{65}{100} = 19{,}630 \text{ cft or } 19.6 \text{ units of } 100 \text{ cft.}$$

		Rs
Hire charges for a shovel for 8 hours @ Rs. 86 72 per hour	..	693.76
Hire charges for 10 dumpers for 8 hours @ Rs 65 20 per hour	..	5216 00
Total .	=	5909.76
Cost per unit of 1000 cft .. = $\frac{5909\ 76}{19.0}$	=	305.2
Say	.	305
Cost per cubic metre .. Rs. 10 80 Say		Rs 11

Unit Cost of Sand Carted by Lorries

10 27 Cost analysis for 100 cft. of sand as observed in February 1966 is given as under :

Hire charges for 7 5 ton lorry per mile .	Rs 1.39
Capacity of the lorry : 1.75 units of 100 cft.	175 cft
Distance of the Halia quarry from the sand dump	22 miles or 35 km
Labour rate per head per day of 8 hours .	Rs 2
(*a*) Collection of sand and loading into lorry manually (Rate based on tender from job workers)	Rs 2 71
(*b*) Conveyance charges for lorry at Rs 1.39 per mile from sand dump to quarry and back $\frac{2 \times 22 \times 1\ 39}{1.75}$ ..	Rs 34.95
(*c*) Formation of approach roads to quarry	1.15
(*d*) Unloading charges from lorries at sand dump	1.00
(*e*) Petty Supervision .	1 00
Total	40 81
(*f*) Contingencies .	1 19
Rate per 100 cft .	42 00
Rate per cu. metre ..	14 8
Say .	Rs. 15

Unit Cost of Surkhi

10.28 Surkhi was manufactured from quarries situated at a distance of seven miles (12 km.) from the dam site. It was pulverised by mechanical beaters so as to pass wholly on 50 mesh sieves and retained not more than 100 mesh sieve At the initial stages ball mills were also used for grinding. The work was done exclusively through contract. The rates varied from Rs. 26.50 to Rs. 31.50 per metric ton during the period 1957 to 1968. Though other rates in the dam increased sharply in the construction period, there was no appreciable increase in this rate due to the following reasons :

(i) There was not much increase in the rate of hydro-electric power which was used for pulverisation.

(ii) The supplies were from only one contractor throughout the construction period. He installed his plant and machinery permanently at the site. If the contract suffered from annual change in the allotment, the new contractor would have to instal his own machinery and arrange for his labour.

(iii) Variation in the labour charges had no appreciable bearing on the cost which included preparation.

RESUME

10 29 The trend of labour rates nearly doubled in the course of ten years Similarly, there was increase in rates of materials like sand and stone by about 50 per cent. The cost of cement which was Rs. 5 per bag at the beginning of the project was Rs. 9 50 at the close of the project Similarly the cost of steel rose from Rs. 600 per metric ton to Rs. 900. The estimate of the project which was sanctioned for Rs 363.80 million rose to Rs. 730 million representing an increase of 100 per cent. This was due not only to rise in rates but also increase in quantities and change in design of several items such as construction of the diversion tunnel, chute sluices and other items not envisaged in the estimate sanctioned previously.

Non-availability of spares and correct tools and equipment was a great handicap in the repair programme. Hence, the machinery could not be utilised to the required efficiency.

When the project was started, provision was made for a maximum flood discharge of 1,088,500 cusecs. This was revised to 1,800,000 cusecs during execution. This resulted in larger size flood gates: 26 Gates 45 ft × 44 ft as against 20 Gates 60 ft. × 30 ft. originally provided

In general, the programmes drawn up for a project would have to be strictly adhered to and the required designs, finances, materials, and

management have to be adequately provided for. In the absence of these timely arrangements, the estimated costs of the projects increase disproportionately and delay the schedule for completion.

To control the rates of cost of the project, there should be always a departmental wing or a state construction corporation, for execution side by side with the works executed by contractors This will lead to a healthy competition and also control of the rates tendered by contractors To control the works being executed departmentally, there should be intensive cost accounting There should be a continuous review of the trend of rates It is also necessary to have daily, weekly and monthly reports of all departmental works and at each stage of construction. At all stages, the records should be so maintained that they should be susceptible of easy check on the spot Slackness on this account will result in losing control on economy and the entire machinery of operations Generally, the executive staff satisfy themselves to the extent that there would not be audit objections in their departmental works But this is not enough Specialised training is necessary to all engineers to execute departmental works, to develop expertise in the control of costs of various works and for effective administration of contract works In the course of their service, the departmental staff should be deputed to the state construction corporations to acquire adequate knowledge in the construction of works on contract Want of adequate attention on the part of departmental officers and slackness in committed departmental obligations, improper investigations and failure in timely supplies of designs and drawings, will give a handle to contractors to demand extensions in the period of contract and to bring up claims for extra payments, causing undue revisions and increases in the cost of projects

TABLE 10.1

(para 10 20)

WAGES FOR WORKERS

(per day of eight hours)

Category	1958 Rs	1961 Rs.	1965 Rs	1966 Rs.	1967 Rs	1968 Rs
Man Mazdoor or helper . .	1.50	1.50	1.73	2.65	3.13	3 85
Woman Mazdoor ..	1.00	1.00	1 44	2 36	2 84	3 56
Head Mazdoor	2.00	2 00	2 00	2.93	3.41	4 13
Mason special	6 00	6.00	6.90	8.34	9 54	10.50
Mason I Class	3.00	3 50	3 74	5.18	6 00	6 90
Mason II Class	2 50	3 16	4 08	4 32	4 56	5.28
Stone cutter I Class	3 25	3.50	4 03	5 47	5.91	7.19
Stone cutter II Class . ..	2.75	3 00	3.45	4.37	4 61	5.57
Carpenter I Class	3.00	3 50	3.74	5.18	6.06	6.90
Carpenter II Class .. .	2 50	2 50	3.16	4 08	4.56	5.28
Jawali (Stone carrier) . ..	3 50	3.50	4 00	4 62	4 90	5.62
Fitter I Class	3 00	3.50	3.74	5.18	6.06	6 90
Fitter II Class	2 50	2 50	3 16	4 08	4.56	5 28
Blacksmith I Class	3.50	3 50	4 03	5 47	5 91	7 19
Blacksmith II Class	2.50	2 50	2.83	3.80	4 04	5.00

Plumber	2.50	3 00	3 45	4 35	4 85	5 57
Mopla (rigger) .	3 00	3 50	4 60	6 04	6.92	7 50
Head Mopla .	4 00	5 00	5 75	7 19	8 00	10 00
Scavenger .	3.00	3 00	3 45	4 37	4 85	5 57
Car driver	5.00	5.00	5 75	7 19	8 07	8 91
Cement or surkhi handling mazdoor	2.00	2 00	2 92	3.16	3.40	4.12
Helper Grade I	2 50	2 50	3 42	3 66	3 90	4.62
Helper Grade II ..	2 00	2 00	2.92	3.16	3.40	4 12
Welder Grade I . .	4 00	4 00	5 44	5 88	6 32	7 16
Welder Grade II .	3 00	3 00	3.92	4 16	4.40	5.12
Turner Grade I .	6 20	6 20	2 76	8 30	8 84	9 80
Turner Grade II	4.00	4 00	5 44	5 88	6.32	7 16
Turner Grade III	3 00	3 00	3.92	4 16	4 40	5 12
Electrician Grade I	3 50	3 50	4.42	4 66	4 90	5.62
Electrician Grade II	2 70	2 70	3 62	3 80	4.10	4 82
Hand driller Grade I	3 00	3 00	3 92	4.00	4 40	5 12
Hand driller Grade II	2 50	2 50	3.42	3.60	3 90	4.62
Blaster	2 70	2 80	3 00	3 62	4 10	4.82
Grinder .	2 70	2 80	3 00	3 62	4 10	4 82
Cut Stone Dresser	5 00	5 30	6 74	7 00	7.62	8 46
Lineman (electrical) .	3 00	3 00	3 92	4 00	4.00	5.12
Fireman . . .	2 50	3 42	3 50	3 80	4 00	4 32
Telephone Operator .	2 20	2 50	3 12	3 40	3 80	4 62
Foreman (Electrical)	7 00	8 00	8 50	10 50	11.00	12 00
Asst. Foreman (Electrical)	7.00	7 00	8 56	9 20	10 00	10 60

CHAPTER XI

FINANCIAL CONTROL

The present accounting system for public works in India has been evolved over a period of a century. The procedures, rules and regulations inherent in this system were laid down at a time when small projects were started at a few places and big projects were few and far between In India since the attainment of independence, the position has undergone a colossal change Gigantic projects like Nagarjunasagar, Bhakra Nangal and Damodar valley development were taken up They had to be completed at a great speed and the usual accounting procedure had to be modified. In these big river valley projects, some significant changes and modifications have been made in the process of accounting and documentation. Yet, the basic structure of public works accounts has not undergone any appreciable change A successful construction engineer should not only be an expert in construction but also have a thorough knowledge of accounting procedures. In this chapter is explained the accounting system and procedures which were adopted for the Nagarjunasagar project.

Organization

11 2 In the Nagarjunasagar organisation, a Control Board was constituted to be in overall charge of the project, including the administrative and technical aspects. The project consisted of the dam and canal organisations, each under the charge of a Chief Engineer. The actual work of construction of the dam and the canal system, including the appurtenant works, was under the direct charge of the Control Board When the project began, it was a joint enterprise of the then Governments of Hyderabad and Andhra which merged later on November 1, 1956 due to the reorganisation of the States. The Andhra and Hyderabad Governments, for whom the Board carried out works, delegated powers to the Board to enter into contracts, sanction expenditure and take other decisions, involving financial commitments in respect of the construction of the dam and its appurtenant works and had directed that orders of the Board should be accepted in audit as conveying the sanction of the respective Governments for their share of expenditure.

11.3 An Administrator was appointed by the Central Government to work in close liaison with the Chief Engineers of the Dam and Canals Organisations of the Project and the Revenue authorities. Mr. S. Chakra-

warti was the first Administrator. He was responsible for putting the project administration on proper lines, and evolving appropriate methods for the Project A Financial Adviser and Chief Accounts Officer was appointed by the Board to render financial advice in respect of transactions pertaining to the Board, make payments for the entire project after cent per cent pre-check and keep the accounts of the project up-to-date Mr. A L. Saksena was the first Financial Adviser and Chief Accounts Officer to head the accounts organisation. He was responsible for evolving 'Accounting and Financial Instructions' for the execution of the project.

11.4 With the concurrence of the Comptroller and Auditor-General of India, the accounts were separated from the audit in this project. The Chief Accounts Officer was responsible for the compilation of the monthly accounts and to submit them to the Accountant-General The duties and functions pertaining to the accounts matters were devolved upon the Chief Accounts Officer, and statutory audit duties and functions, on the Accountant-General, who was nominated by the Comptroller and Auditor-General as the auditor of the project accounts A Resident Audit Officer of the status of a Deputy Accountant-General was posted by the Accountant-General for the concurrent audit.

11.5 Adjustments with other governments and departments was eliminated from the accounts of the project. Such transactions were, therefore, settled in cash. Pay and Accounts offices working under the control of the Chief Accounts Officer were located at the site of the dam. The Pay and Accounts Officers had to pre-check all the claims and were responsible for compilation of accounts. They were the principal disbursing officers of the project.

11 6 The Executive Engineers and the Assistant Engineers of the Dam Organisation had no cheque-drawing powers. However, for certain categories of payments in respect of works relating to the Canals Organisation for branch canals and distributaries and field channels, limited cheque-drawing powers were delegated to them. The intention behind the establishment of a separate and independent Pay and Accounts Organisation was only to have cent per cent pre-check of all claims and also to relieve the engineering personnel of a part of their responsibilities for payments and accounts documentation.

11.7 The headquarters of the Deputy Chief Accounts Officer were at the dam site. The Pay and Accounts Offices were located at the dam site and along the canals. There was a separate Accounts Officer attending to the inspection of divisions and offices. The Deputy Chief Accounts Officer was in supervisory charge of the Pay and Accounts

offices for both the dam and canals organisations He rendered the monthly accounts to the Accountant-General The Deputy Chief Accounts Officer took guidance from the Financial Adviser and Chief Accounts Officer on all matters. Thus, the Nagarjunasagar project had a well knit accounts organisation and different units working with great cohesion to deal with the various accounting problems arising in the day-to-day administration of the project.

Accounting Procedure

11.8 The major head of account for the project was '98-Capital Outlay on Multi-Purpose River Schemes—Nagarjunasagar Project' under which there were three minor heads, the Dam, the Right Canal and the Left Canal. Under each of these minor heads, there were four sub-heads viz., Works, Establishment, Tools and Plant, and Suspense. Under these heads of accounts, the Executive Engineers, Superintending Engineers and the Chief Engineers sanctioned estimates within their powers The expenditure was booked estimate-wise and reconciled with the accounts which were compiled detailed head wise. Outstanding features peculiar to this project were that all transactions with other projects and departments etc. were made in cash.

11.9 The store accounts in this project were maintained on the store receipt books, store issue books, priced store ledger system and not on orthodox public works system This was modelled on the system which is prevalent in commercial concerns. The Rates and Costs Committee had recommended the adoption of this procedure The documentation under this system constituted bin-cards, store receipt books, store issue books and priced store ledgers

The Nagarjunasagar accounts organisation could take legitimate pride, to a great extent, for proper maintenance of the accounts and quick payment and in up-to-date documentation of basic accounts.

The various rules of procedure have been described in the following paras.

Procedure for Government Sanctions

11.10 To enable the Board to perform its functions of overall co-ordination, estimates and other proposals involving expenditure (including budget) required the sanction of the State Governments as well as of the Board The Board then would scrutinize these proposals from a broad angle of co-ordination and uniformity and offer its remarks, if possible, within a week from the receipt of the proposal In the meantime, if found necessary, the respective governments would authorise expenditure in exceptional cases before receipt of the remarks referred to above

Functions of Divisions and Sub-Divisions

11.11 The Divisional Officers were relieved of the duty of issuing cheques They were also not required to furnish consolidated monthly accounts to the Accountant General At the same time they would, as hitherto, remain responsible for the correct maintenance of initial accounts and records, which form the basis of claims for payment, for correct allocation, and for maintaining complete records of expenditure on works. Initial records such as measurement books, muster rolls, work abstracts, materials at site accounts, stock accounts, register of works, contractor's ledger, suspense registers and register of deposits, were maintained by the Divisional Officer in the forms contained in the accounts code For assisting Divisional Officers in the discharge of their duties, a Divisional Accountant was posted for each division

11.12 It follows that Sub-Divisional and Divisional Officers were given imprests or temporary advance. The amount of the permanent imprest was calculated at the rate of Rs 1,000 for each Divisional Officer and Rs. 500 for each Sub-Divisional Officer. From out of this imprest, the Divisional Officers issued sub-imprests to the Sub-Divisional Officers of an amount not exceeding Rs 500 and to the Sectional Officer not exceeding Rs. 100.

11.13 The limited muster roll payment which should be made from out of the imprest by the Sub-Divisional Officer was Rs 500 When the muster roll exceeded this amount, the Divisional Officer would obtain a temporary advance from the Pay and Accounts Officer with a certificate given by him that the muster rolls for the amount claimed had been received from the Sub-Divisional Officer and were under check or had been checked Claims of the nature of contingent charges not exceeding Rs. 25 and emergent claims were also paid from the imprest

11 14 The transactions of the sub-imprest holders were invariably incorporated in the accounts of the imprest holder before they were submitted to the Pay and Accounts Officer for recouping The imprest holder ordinarily rendered complete accounts to the Pay and Accounts Officer with vouchers once a fortnight The accounts relating to the second fortnight had to be sent on the 25th of the month, to enable the Pay and Accounts Officer to incorporate the transactions in the accounts of the month.

Execution of Works

11.15 No work was started before the detailed estimate had been sanctioned, funds allotted, and necessary agreement executed by the competent authority. No claim pertaining to works was ordinarily

presented for payment before the formalities specified above had been completed and sanction communicated to the Pay and Accounts Officer. In case of rare emergency, the Divisional Officer dispensed with these formalities, provided the case was within his power of sanction. Otherwise, the prior approval of the Superintending Engineer or the Chief Engineer, according to their powers of sanction, was necessary. In all cases, where the formalities were dispensed with, the Divisional Officer had to commence the work immediately after the decision was taken, communicated to the Superintending Engineer or the Chief Engineer and to the Chief Accounts Officer, with the following particulars :—

(*a*) Name of work.

(*b*) Estimated amount

(*c*) Whether estimate had been sanctioned.

(*d*) Whether work is executed by contractor or departmentally.

(*e*) Whether an agreement had been entered into. (For contract Work).

(*f*) Rate or rates at which the various items of work are being executed

(*g*) Amount of estimated liability before the prescribed formalities could be completed.

(*h*) Detailed reasons for execution of work in anticipation of formalities

(*i*) Authority permitting the execution of work.

Ordinarily more than one payment was not made for such works. The second payment was not made unless sanctioned by the Superintending Engineer or the Chief Engineer.

Communication of Sanctions

11.16 Copies of sanction, relating to works or establishment or other matters accorded by the various authorities, were endorsed to the Pay and Accounts Officer as and when they were accorded. Copies of sanction for expenditure accorded by the Superintending Engineer, the Chief Engineer or the Board were, in addition, communicated to the Deputy Chief Accounts Officer. All sanctions had to be accompanied by copies of relevant documents. Full classifications of expenditure giving the major, minor and detailed heads of account had to be given in the sanction.

Similarly, copies of all agreements or purchase orders entered into with firms or contractors for execution of works or supply of materials had to be sent to the Pay and Accounts Officer as soon as such agreements

were entered into or purchase orders issued In respect of sanctions accorded by authorities higher than the Divisional Officer, copies of sanctions had also to be sent to the Resident Audit Officer who was holding his office at the dam site The sanction of estimates and agreements or the purchase orders had to be sent along with scrutiny slips. Sales tax was payable only if the purchase order or contract specifically provided for such payment. Otherwise, the rates at which supplies were to be paid for the stores supplied was deemed inclusive of sales tax.

A consolidated report of sanction to the estimates accorded during the month had to be sent to the Deputy Chief Accounts Officer and the Pay and Accounts Officer not later than the 5th of the month succeeding that to which it related. For convenience, these sanctions were serially numbered for every financial year, for each office of sanction

Receipt of Money

11.17 Particulars of miscellaneous cash realised by officers of the Project had to be kept in a separate register The cash realised by the project officers had to be paid as soon as possible into the treasury or bank on behalf of the Pay and Accounts Officer concerned to the credit of ' Public Works Remittances—I.— Remittances into Treasuries '

11.18 The remittances into the treasury had to be made by means of a challan in duplicate. The challan receipt credited by the treasury or sub-treasury had to be forwarded to the Pay and Accounts Officer before the end of the month with a statement showing the particulars entered in the register of miscellaneous cash receipts. In every case, project officers had invariably to issue temporary receipts at the time of receipt of money. On receipt of the Challan, the Pay and Accounts Officer was to issue to the project officer a permanent receipt for onward transmission to the party concerned

11 19 Earnest money was received along with the tender in the form of a draft or cheque certified as good, drawn in favour of the Pay and Accounts Officer. Thus, cheques etc had to be entered in a register and kept with the Divisional Officer or other authorities only till a decision was taken regarding the acceptance or otherwise of the tenders. All tenders had to be entered in a special register As soon as the tender was accepted, the cheques or drafts tendered by the unsuccessful tenderers had to be returned to them by the Divisional Officer or the other authority. The acknowledgement of the party had to be entered in the register. The entry releasing the cheque or draft in favour of the party was to be signed by the Pay and Accounts Officer concerned.

11.20 After acceptance of the tender, the draft or cheque pertaining to it was passed on by the Divisional Officer to the Pay and Accounts Officer who was to take it in his accounts and issue an acknowledgement.

Intimation of Requirement of Funds

11 21 On the orders of the Government, the Accountant-General was to issue a letter of credit beyond which the treasury or the bank would not permit drawals.

The Pay and Accounts Officer had to send a consolidated statement of the requirements of the project officers to the Chief Accounts Officer on the 25th of the month. The Chief Accounts Officer on receipt of the requisitions, was to apply to the Accountant-General for issue of credits.

The Chief Accounts Officers had to obtain the letter of credit in time from the Accountant-General for drawing cheques on the bank concerned The Chief Accounts Officer, on receipt of the letter of credit was to distribute the money to the Pay and Accounts Officers, who had to take care to see that they would not issue cheques in excess of the letter of credit.

Tools and Plant

11.22 Tools and plant were classified as ordinary and special tools and plant.

The ordinary tools and plant constituted the small tools and equipment required for the general or ordinary use of each division. They were generally issued to the subordinates for use on works, after which they were returned to the sub-divisional or the sectional stores They were rarely hired out to the contractors. Their cost was charged to the minor head, ' Tools and Plant '. No part of the expenditure was charged to the individual work on which they were used. The sub-heads of the minor head, ' Tools and Plant ' were : ' new supplies ', ' repairs and carriages ', ' deduct recoveries', and ' lumpsum charges creditable to other Government departments etc '

Ordinary Tools and Plant

11.23 Examples of ordinary tools and plant were augers, axes, crowbars, drills, pickaxes, spades, wrenches, office furniture, survey and drawing instruments.

Special Tools and Plant

11 24 Examples of special tools and plant were · tractors. bull-dozers, road rollers, air compressors and pumps, that were required for performance of a specific job such as earth work, concreting etc Ordinary tools and plant did not cost much whereas special tools and plant were costly. A ' use rate ' per hour or other unit for each item of special tools and plant was fixed. These rates were in two parts—one for depreciation and the other for maintenance and operation

11.25 The estimate for maintenance and repairs of the special tools and plant was to be sanctioned under the head ' Maintenance ' to be opened under the same head under which the cost of the special tools and plant was debited. Monthly adjustments had to be made debiting the works concerned on which the tools and plant had been used based on the use rate. Any balance at the end of the year under the maintenance estimate after making these adjustments was debited to the work on which the tools and plant had been mostly used during the year In any case of doubt, whether the particular item of tools and plant should be treated as ' ordinary ' or ' special ' the matter would be referred to the Chief Engineer for decision

Transfer Entries

11 26 Transfer entries, that is, entries intended to transfer an item of receipt or charge from the account of a work in progress or of a head of account to the account of another work or head, was made in the following cases .

To correct errors of classification in the accounts kept by the Pay and Accounts Officer.

To adjust by debit or credit to the final head of account or work, the item outstanding under suspense account or a debit head

To bring to account certain classes of transaction which did not pass through the cash or stock accounts, for example :

(i) for credit to ' Public Works Deposits ' on account of balance due to contractors where delay was caused in receiving final payment for more than one month after the bill had been passed.

(ii) for debit to ' Miscellaneous Public Works Advance ' of amounts found due from contractors on the passing of final bills if an immediate recovery was not practicable

(iii) for credit to the head 'Receipts and Recoveries' on 'Capital Account' of certain items of revenue, not recovered in cash, for example, supervision charges, on 'Sales on Credit' of stores, sold to private parties.

(iv) to incorporate in the accounts of works certain liabilities like unpaid balance of partly paid running account bills or muster rolls, etc.

(v) to relieve the account of a work in progress or items which have ceased to be debitable to the estimate for the work, and suspense charges which can no longer be taken within the accounts of the work, for example, 'materials' transferred to other works or heads of account

Measurement Books

11.27 Each measurement book contains instructions to be followed. In addition to this, the following important instructions had to be observed :

(*a*) The measurement book entries should be in neat handwriting, the figure being easily decipherable for the purpose of check.

(*b*) The words adopted to describe the items of work in the measurement books should be identical with those contained in the agreement bonds, written understandings or work orders. These words should also be identical with those adopted in the relevant estimate.

(*c*) The facts of measurement and check-measurement should be recorded in ink and in a prominent place

(*d*) The measurement and the abstracts in respect of each bill should be recorded in the measurement book in consecutive pages and should not be interspersed with similar items relating to other works.

(*e*) Sufficient space should be left at the end of the abstract for the record of the pay order and the 'paid' stamp in the Pay and Accounts Office.

(*f*) Measurements for supplies should be recorded not when the bills were received, but on the date on which the supplies had been received, whether a bill had been received or not.

(*g*) Entries had to be made in measurement books for work done on nominal muster rolls with work charged establishment when such work done is susceptible of measurement. When the work is not susceptible of measurement, the fact should be

recorded in the muster rolls and the pay bill of the work charged establishment A separate measurement book should be used for this purpose.

Maintenance of Works Accounts Records and Registers

11 28 The Divisional Officers would maintain all the initial account records in their offices The register of agreements should be maintained. The postings in register of works, contractors' ledger and the suspense and deposit registers, however, had to be made simultaneously, with the presentation of the claim to the Pay and Accounts Officer. The posting in the various registers should be reconciled with the figures in the corresponding registers of the Pay and Accounts Officer by the 10th of next month and a certificate to this effect had to be recorded by the Divisional Officer.

Pay Bills

11.29 Bills for pay and allowances including travelling allowances had to be prepared in the prescribed forms. To ensure disbursement of pay on the first day of the month, the pay bills of regular establishment had to reach at least five days before the last working day of the month to which the claim related

Work-Charged Establishment Bills

11.30 Pay bills for the work charged establishment had to be sent in the prescribed form accompanied by a covering memorandum in abstract headed 'Work-Establishment' These bills had also to be sent five days before the last working day of the month in the same way as for the regular establishment. The drawing officer would be responsible for withholding payment of the 'Work-Establishment', the pay and allowances relating to the dates of absence, if any, between the dates of the preparation of the bills and the end of the month Income-tax deductions, if any, should be made at the bottom of the bill and the net total for which a cheque was required to be drawn should be entered The amounts paid by the Pay and Accounts Officer for the payment of the wages of the work charged establishment and the men employed on the nominal muster rolls would be treated as temporary advances pending adjustment on the basis of accounts rendered. The Divisional Officer would be responsible for seeing that the advances were adjusted within a period of two weeks from the dates of the advance. If any advance was outstanding for more than a month, further advances were liable to be stopped.

Contractors' and Suppliers' Bills

11.31 Bills in favour of suppliers, contractors and piece workers had to be prepared in one or the other Public Works Account Code forms. The bills had to be completed in the following respects before they were sent to the Pay and Accounts Officer together with the relevant measurement books :

(i) The following particulars had to be given on each bill, the classification being noted fully and clearly :

(*a*) Name of division.

(*b*) Name of sub-division

(*c*) Name of work as sanctioned

(*d*) Complete classification, major, minor and sub-heads, etc.

(*e*) Number and date of contract or agreement or purchase order.

All bills were to be passed by the Officer authorised to do so, and his authority for passing the bills could not be delegated by him to any subordinate officer

(ii) The number and date of the estimate, the agreement, written understanding or work order had to be marked in red ink both in the measurement book and the bill.

(iii) Details of deductions of the cost of materials issued to contractors had to be indicated clearly giving the quantity and the amount, quoting reference to the unstamped receipt for each item in a separate sheet of paper attached to the bill giving reference.

(iv) Reference to the number and date of the correspondence with which the unstamped receipts were sent to the Pay and Accounts Officer had to be given in the statement referred to in the preceeding para.

(v) The correct spelling had to be adopted giving the name of the contractor or the supplier in the measurement book, the bill and the agreement. There was to be no discrepancy in the spelling adopted in these documents, as the spelling adopted in the cheques had to be that given in the bills. It had to be remembered that the banks dishonoured cheques if the spelling was not correctly given therein. The bill had to be pre-receipted

by the contractors and the receipt had to be for the gross amount The signatures of the contractor for acceptance of the measurement were obtained both in the bill and the measurement book.

(vi) Except those relating to Government departments, bills were rounded off to the nearest rupee (half and above being rounded as a unit) to facilitate the maintenance of accounts only in rupees For this purpose, deductions made from the bills of suppliers to the contractors were rounded off.

(vii) The Pay and Accounts Officer had a drawing account with the bank and the sub-treasury. The drawing officers had to clearly indicate in all bills the name of the sub-treasury or the bank on which the cheques were desired to be drawn As far as possible, the request was to be complied with.

Works to be Measured and Paid Promptly

11.32 Delay in payment leads to rise in rates and must be avoided at all stages Works done or supplies received from contractors had to be promptly measured and the bill after check, transmitted for payment to the Accounts Officer without delay. Requisitions of money for payment of muster rolls and other emergent bills were transmitted to the Accounts Officer on the day of receipt

Any delay of a week or over had to be explained in the memorandum accompanying the bills

Precautions in Transactions

11.33 Cheques were, as a rule, issued only to the Divisional Officers who presented claims either directly or through messengers In case cheques had to be sent through messengers, the Divisional Officers sent to the Pay and Accounts Officer a panel of names of messengers, who were authorised to receive cheques. It was necessary for the Divisional Officers to choose messengers of known reliability and appropriate status The Divisional Officer and not the Pay and Accounts Officer were responsible for cheques delivered to the messenger. No cheques were handed over by the Pay and Accounts Officer to contractors except when a specific request to that effect was made by the Divisional Officer.

Except as prescribed in the last sentence above, the acknowledgements for cheques delivered by the Divisional Officers to persons (other than Government servants) were submitted to the Pay and Accounts Officer within four days after payment. The slips with which cheques were to be sent to the Divisional Officer and with which acknowledgements had to be sent by the Divisional Officers to the Pay and Accounts Officer were prescribed.

If, on request, cheques had to be sent by post, instead of being delivered in person, they had to be sent only by registered post, acknowledgement due In the case of open cheques delivered in person or through messenger, the cashier took all reasonable precautions against fraud.

All miscellaneous cash receipts released by the project officers and remitted to the Pay and Accounts Officer were not, as a rule, to be utilised for expenditure. If, however, such receipts were utilised for expenditure to any extent, a self-cheque for the amount utilised had to be drawn at the end of the month and remitted into the nearest treasury or bank along with the unutilised cash received.

The cash in chest on any day did not generally exceed Rs 5,000. If there was a likelihood of excess over the limits, the surplus cash had to be remitted into a sub-treasury or a bank

The Pay and Accounts Officer at his discretion and subject to availability of cash in the chest, made emergent payments in cash. If the cash in the chest got depleted after making such cash payments, adequate cash should be obtained from the bank against 'self' cheques.

Cent per cent arithmetical check had to be conducted in the Pay and Accounts Office, the fact being indicated by a rubber stamp with full signature of the clerk concerned. It followed, therefore, that in the case of payments for works, all the measurement books had to be obtained

As soon as the 'pay order' on bills was signed by the Pay and Accounts Officer, the clerk crossed all the concerned pages by red ink in diagonal line The cash book voucher number had to be noted as a part of the payment certificate

A list of payments made during the course of the day was sent to each divisional and other drawing officers giving particulars of the bill number, date, amount, cheque number and date and amount to reach them the same day or the next day.

Compilation of Accounts

11.34 The accounts of the project were compiled by the Pay and Accounts Officer, directly working under the Chief Accounts Officer, and were submitted by the Chief Accounts Officer to the Accountant-General on the due date.

Reconciliation of Accounts

11.35 The accounts and registers maintained in the offices of the Pay and Accounts Officer were to be reconciled with the corresponding registers and accounts maintained by the Divisional Officers and all discrepancies settled before the 10th of the next month. A certificate to this effect had to be recorded in the relevant register by the Pay and Accounts Officer.

Duties and Personal Contacts

11.36 The duties of the clerks, Superintendents and the officers in respect of claims represented for pre-check were the same as those of the auditors, superintendents and the officers of the audit office, as laid down in the Audit Manual and the Manuals of General Administration Department etc Close contact had to be maintained between the project officers and the Pay and Accounts Officers at all levels There was as far as possible, full and free discussion on any problem that might arise and efforts were made to settle them in a spirit of mutual help and co-operation

Nature of Contracts

11 37 The following forms of contract were used in the execution of works :

Piece-work agreement,
Work order and
Item rate contract

The piece-work form was used when tenders or quotations were not invited and the cost of the work was less than Rs 2,500. It was also used for larger works when it was considered necessary to start work immediately pending its letting out on a regular contract In such cases the out-turn on the piece-work agreement was cancelled as soon as the work was let out on a regular contract

11 38 The use of the work order form was restricted to works costing Rs. 7,500 and below. The form was adopted when the work was given without calling for tenders in emergencies or on obtaining competitive rates from a few contractors without calling for open tenders.

11.39 The Item Rate Contract form was adopted for all contracts costing above Rs. 7,500 and even for lesser amounts when open tenders were invited. The piece-work agreement and the work order forms were

adopted only for works which were likely to be completed within six months In the piece-work agreement there was no reference to the quantity or time but in the work orders the quantity and time for completion and the penalty for non-completion within the period were specified In the case of work done on piece-work and on work order costing below Rs. 2,500, the Executive Engineer could, at his discretion, waive deposit of earnest money, but 10 per cent recovery towards security deposit from the running bills, if any, was made.

11.40 In case of item rate contracts, the contract documents comprised of

(i) The notice inviting tenders

(ii) The form of tender to be used

(iii) The schedule of quantities of work

Reference to standard specifications for each item of work should be given in the tender schedule.

Where deviations from standard specifications were proposed, then complete specifications were given.

(iv) A set of complete drawings

(v) A set of conditions of contract together with a copy of the form accompanying the tenders

Call for Tenders

11.41 Wide publicity as prescribed below was given to the notice inviting tenders

(*a*) A copy of the notice was to be sent to all the Project divisions and the Chief Engineer's Office

(*b*) For works costing above Rs. 25,000 and for supplies above Rs 1,000 a small notice was inserted in a local English paper and a regional language paper.

(*c*) For works costing above Rs. 500,000 and for supplies above Rs 100,000 notices were inserted in leading daily papers.

For works and supplies below Rs. 1,000 it was sufficient if only quotations from local contractors or suppliers were called for, but for those below Rs 200 no such quotations were necessary.

All notices calling for tenders were in the standard form and serially numbered, a proper register being maintained for the purpose. They were issued after the authority competent to accept the tender had approved the contract documents. The notice inviting tenders had to

be carefully prepared. The use of the symbols % and ‰ in the schedule of quantities accompanying the notices inviting tenders was prohibited, and the words, per hundred and per thousand were written.

All forms issued to tenderers were clear, legible and unambiguous The list of items might also contain a column for 'amount' after the column 'rate tendered' and the contractor had to calculate the amount of each item and enter in the column The contractor had to also total these amounts both by sub-head and grand total

Tender forms were properly accounted for, and sold only to approved contractors, and should invariably bear the name of the purchaser. Any form which was issued either for sale or for office use were issued under the signature of the Divisional Officer.

The following time limits between the dates of call for tenders were laid down, but the period might be varied at the discretion of the officer competent to accept tenders :

Seven days when the cost of work or supplies was within Rs 10,000.

Fifteen days when the cost of work or supplies was within Rs 50,000.

One month when the cost was above Rs. 50,000

Receipt of Tenders and Their Acceptance

11 42 To avoid the possibility of tampering with the original tenders during the intervals, they were in the office for the preparation of a comparative statement, the officer opening the tenders should invariably date and initial all the documents, attest all the corrections, number them in red ink and sign each page of all the contract documents The competent authority might reject any tender containing mutilations

11.43 The tenders should be received by the Divisional Officer and kept in his personal custody. They should be entered by the Divisional Accountant into a register giving the name of the tenderer and the time and date of the receipt of the tender When the tender was opened, the officer opening the tender should record whether the earnest money was received and other remarks found necessary. He should also endorse the time and date of the opening of the tenders and should obtain the signatures of the tenderers, who may be present, in the register The Divisional Accountant and the tenderers should be encouraged to be present at the time of opening of tenders. The rates tendered should be read out to the tenderers as far as possible

11 44 A complete comparative statement of all tenders received in response to the notice should be drawn up in the Executive Engineer's

office. Care should be taken in preparing and scrutinising the comparative statement of tenders to guard against arithmetical and other mistakes If the conditions of a tender were unusual or differed from the notice, special attention should be invited to them and the financial effect, if any, brought out prominently. Failure to do these might result in work being awarded to a contractor whose tender was not the lowest acceptable one.

11.45 The detailed arrangements for proper check of tenders and preparation of comparative statements were left to the Divisional Officer, but any such arrangement must provide that :

(i) The comparative statement should be prepared in the technical section and it should be checked by the Head of the Section. The statement should be signed by the staff who prepared it and also by the head of the section as having checked it.

(ii) The statement prepared by the Technical section should be checked by the Divisional Accountant. The test check of computed and checked tenders should be sufficient to satisfy him reasonably that the checking work has been properly done. The Divisional Accountant should also see that the comparative statement correctly incorporated the totals as checked in individual tenders.

(iii) The Divisional Officer himself should make an intelligent scrutiny of the tenders and the statements

(iv) The Divisional Officer should make proper arrangements for the safe custody of tenders and comparative statements while computations were being made in his office.

11 46 When contractors signed their tenders in any Indian script or could only write their name in English, the amount of the tender should be written in the contractor's own handwriting in Indian script and in the case of an illiterate contractor, the amount of the tender should be attested by one of the witnesses. All corrections should be carried out neatly and clearly endorsed for attestation by the authority concerned. The fact of acceptance of a particular tender and reasons therefor should be recorded in the comparative statement which, along with the rejected tenders, should be recorded in the division concerned

11.47 Alterations in rates after submission of tenders but before acceptance should not be allowed except for bonafide mistakes and under the orders in writing of the authority competent to accept the tender who should see that by such action he would not be unfair to other

tenderers When there was a keen competition for a particular work, alterations of a tendered rate might be a very serious matter.

11 48 Tenders which are beyond the Executive Engineer's powers of acceptance, should, along with the relevant remarks be submitted in a sealed cover and addressed by name to the Superintending Engineer concerned along with the Executive Engineer's recommendations If a tender was beyond the powers of the Superintending Engineer, he should forward the documents to the Chief Engineer with his remarks. The tender, after acceptance, became the contract and should be carefully recorded in a register and placed in the divisional office The Executive Engineer would prepare and send copies of the contract to the Pay and Accounts Officer (one copy) ; the Financial Adviser (one copy of contracts exceeding Rs. 50,000) and the Resident Audit Officer (one copy of the contract executed by the Superintending Engineer and the Chief Engineer).

Subsequent variations, if any, in the contract accepted by the authority other than the Executive Engineers should be communicated to the Financial Adviser and Chief Accounts Officer, to the Pay and Accounts Officer and the Resident Audit Officer direct by the authority authorising the variations. Such variations should be made by means of separate letters or documents.

Earnest Money and Security Deposit

11.49 The amount of earnest money required to be furnished by the tenderers should generally be fixed at 2½ per cent of the estimated cost of the work, subject to a maximum of Rs 50,000. The earnest money might be tendered in the form of cash alone if it did not exceed Rs. 100. Otherwise, it should be in the form of a bank draft or a cheque, certified as good, drawn in favour of the Pay and Accounts officer of the project In the event of acceptance of a tender, a further security of 7½ per cent should be deducted from each running bill, subject to a total maximum of Rs. 200,000.

11 50 Contractors might, however, deposit Rs. 50,000 in cash or in Government securities or a bank guarantee with the Financial Adviser and Chief Accounts Officer as standing earnest money These contractors would be exempted from furnishing earnest money along with their tenders A deduction of five per cent security would be further made from their running bills, subject to a maximum of Rs 1,50,000.

Progress Reports

11.51 Progress reports for contracts costing Rs 1,00,000 and over should be submitted by the Divisional Officers to the Superintending

Engineer and the Chief Engineer every month. The form duly filled in should be submitted to the Superintending Engineer by the fifth of the following month. He, with his remarks, should pass it on to the Chief Engineer, so as to reach him by the 10th. The Chief Engineer would return the form to the Divisional Officer concerned direct before the end of the month. The forms would be submitted every month in the same manner. An office copy of the progress report should be maintained in the offices of the Divisional Officer, the Superintending Engineer and the Chief Engineer The dates of receipt and despatch of the report in the offices of the Superintending Engineer and the Chief Engineer should be noted on the first page of the report, the remarks of the Superintending Engineer and the Chief Engineer being recorded on the second and third pages respectively.

Store Accounts

11.52 For the supply of the stores required by the officers of the Nagarjunasagar dam organisation, they placed indents on the stores division. The store materials generally required were machine spares of electrical or Diesel equipment, machine parts, electric bulbs, petrol, oil, cement and steel. The stores division prepared the purchase estimates and obtained sanction to the suspense stock. It was competent only to procure items from the list of the rate contract from the Director-General of Stores and Disposals. Items not covered by the list could be procured only with permission of the Chief Engineer irrespective of Financial limits The unit officers would themselves procure such items directly by observing the formalities such as sealed tenders and quotations as per the departmental code duly charging them to the work estimates.

The stores were received free over rail at Macherla as it was the nearest railway station. They were also received through the Stores Sub-Division at Hyderabad by rail. There was an Assistant Engineer in-charge of stores assisted by store-keepers for receiving the materials. For the materials purchased on rate contracts, test certificates in triplicate were sent by the inspectors One copy of the certificate was sent to the Pay and Accounts organisation, and another to the Stores Division. A third was retained in the receipts section of the Sub-Division. Any damage to the materials despatched by train or lorry or shortage at the time of their receipt was noted by the Stores section.

The materials, soon after receipt, were entered by the receipt section in Stores Receipt Book (S.R B.) which was like a measurement book. These entries were made in triplicate copies, one copy forwarded to the Pay and Account Officer's organisation, one copy to the division office and the triplicate copy retained in the Receipts Section.

The indenting officers would place indents in Stores Indent Books in quadruplicate, duly noting their requirements of the materials and the estimate to which they were chargeable On issue of the materials by the stores division, entries were made in S I Bs (Stores Issue Books) and S I B , copies were sent to the indentor, the Pay and Accounts organisation, the Division Office and the quadruplicate retained in the Stores Section.

Soon after receipt and entry of the materials in the S R Bs. they would be tagged with a tag card to facilitate easy identification Reference would be made on the tag card for the part number of the machine as indicated in the manuals published by the supplying firms. The materials were check-measured by an Assistant Engineer, in the receipt section

The materials, after they were duly verified and check-measured, were shifted to the Central Stores in separate bins where they were stored for supply and for future storage as spares by the requisite divisions in the dam The details of each item were entered on a bin card indicating the details of materials obtained, indented, issued and the balance in stock at a glance at all times Much of the labour was saved in the system to find out the particular location of a specified material, including its stock position.

A tag card was attached for each part which contained the following information :

Nomenclature
Part number
Issue rate
Bin card number
Bin number

Details given in the bin card are shown in Table 11 1 at the end of the chapter

Organisation of Stores

11.53 The stores division was headed by an Executive Engineer. Assistant Engineers holding the following five sub-divisions were classified into categories as follows :

Petrol, Oils and Lubricants ; (P O Ls)
Machinery spares
Electrical spares
General items
Cement and steel

The Stores division comprised of a huge number of workcharged establishment for procurement, maintenance, accounting, watch and ward and disposal of the materials.

Issue Rate of Material

11.54 Issue rates of materials were decided taking the following points into consideration :

(i) The purchase rate of materials as per purchase orders placed.

(ii) P.O Ls were classified under fast moving stores.

(iii) Machine spares such as those for heavy machinery, earth moving machinery and cranes, were slow moving stores.

(iv) Electrical goods, steel and cement were also considered to be fast moving since they were indented for immediate consumption.

While calculating issue rates, five per cent was added to the purchase value for storage charges for fast moving articles and three per cent for the slow moving. When the materials were issued outside the Dam organisation, centage charges were also levied at ten per cent on the purchase value. If the stores were issued to contractors and private bodies, sales tax was also levied as per rules in vogue.

Adjustments of Accounts

11.55 Realisation of amounts for stores issued would be by adjustment through the Pay and Accounts Officer by Stores Issue Books within the organisation and by bills of costs outside the organisation and to contractors The stores stocks suspense estimates were cleared by passing credits through S.I.Bs, and cash payments as the case might be.

Stock Verification

11.56 Within the Stores Division the stocks were verified by inspection and control staff in the early stages of the Project. But later due to decrease of workload, this was done by a section of the Stores Division itself. The periodicity of such stock verification was once in three months or as per necessity. The stock verification returns were passed on to the Pay and Accounts Organisation and to the Division Office. They were tallied with the stock accounts of various Sections.

Losses in Stores

11.57 Allowances were made for wastage, driage of oils, shrinkage of timber etc. As the life of certain materials would expire due to excessive storage periods, sufficient precautions were taken to procure only those materials which were immediately needed by the indenting divisions for use. For example, the life of rubber products such as tyres and tubes, batteries,

electrical goods and cement would considerably be reduced if stored for long periods. Petrol and Diesel would evaporate considerably in hot and dry weather. So lesser stocks or the correctly required quantities were procured

Cost Accounts

11.58 Intensified costing was introduced in respect of works :

(i) executed departmentally or by job workers or contracts on labour rates,

(ii) materials being supplied departmentally, and those relating to the maintenance, repairs and replacement of machinery and equipment

The major objectives to be served by the costing are to furnish the maximum amount of information from both operation and cost angles, to present in the most practicable way, facts that revealed the actual performances and aid in the attainment of high standards of efficiency and, therefore, of realisation of maximum economy, and to aim in determining operational policies.

The first stage in any costing is the estimate. Apart from the physical unit rates, the estimate should contain a break-up in terms of labour, materials, plant and equipment cost and other incidental charges. In preparation of an estimate, there should be adequate subheads to meet the requirements of costing.

11.59 The principal material required for costing of works executed departmentally or on labour contracts is a report from the field officers discussed hereunder :

A regular weekly report should be given containing the nature, the number and cost of labour employed each day in the week, a description and the quantity and the cost of materials consumed during the week; particulars of the use of plant and machinery on the work calculated at the use rates fixed for such equipment, the out turn in terms of units and particulars of expenditure, incidentals incurred i e., workcharged establishment and expenditure on items other than those mentioned above including those which are incurred out of the contingencies of the work.

For each vehicle or heavy machinery, a separate estimate was sanctioned. For vehicles like jeeps, cars and trucks, log books were maintained , and for the heavy machinery such as tractors, graders etc , daily log sheets were prepared.

The log books would be written up by the drivers, while the log sheets would be prepared daily by the subordinate in-charge. From those records, the Subdivisional Officer should prepare the following statements and submit them to the Cost Section so as to reach it on the first day of the week following that to which it relates :

(i) Machine use report in respect of heavy vehicles.

(ii) A copy of the daily log sheet for vehicles.

The cost section would analyse the information given in the weekly report and prepare the machine cost report which brought out the number of hours the machine worked, breakdowns, its condition and the hourly rate of its use as compared to the standard use rate. A copy of this report would be sent for information to the Executive Engineer, the Superintending Engineer and the Financial Adviser.

Monthly Reconciliation

11.60 Monthly reconciliation of figures of work and expenditure between the costing and accounting sections was made. As the daily measurements of work indicated in the field reports of the Assistant Engineers would be only approximate, all measurements of works had to be more accurately taken to the end of the month and mentioned as such in the cost report. To bring about reconciliation of the figures of expenditure on the two sections, those relating to the accounting side had to take into consideration the unliquidated liabilities.

General Remarks

11 61 A Good accounting system is an essential requirement of national projects Nagarjunasagar was the first river valley project in India in which all book adjustments were eliminated. This had a salutory effect on all the expenditures being brought to accounts immediately and not held in suspense for long periods as is the case in some of the other projects Other salient features of the accounts were :

(*a*) The Chief Accounts Officer took the responsibility for pre-check and payment of all claims for works and establishment in respect of the project and for compilation of accounts

(*b*) Executive Engineers were relieved of the duty of issuing cheques and furnishing monthly consolidated accounts to the Accountant-General They were responsible only for the correct maintenance of initial records, which form the basis for claims for payments and for maintaining records of expenditure on works,

(c) The Accounts Officer compiled all the monthly accounts and schedules. These accounts and vouchers were made available for Concurrent Audit to the Accountant-General who located a small staff alongside the Accounts Office, for the purpose

The above arrangements and this system of accounting resulted in accounts being made up-to-date in the audit by the Accountant-General, a feature unknown in other projects

RESUME

11.62 This system of pre-audit and accounting is excellent for projects as far as accounting procedures are concerned But it is not adequate to the needs of the main objective which is to relieve the executive of all responsibilities in the matter of accounting As the system stands today, a large part of the accounting is still left to the executive, meeting the main objective only partially For instance, the responsibility for maintenance of initial accounts such as materials at site accounts, tools and plant accounts, maintenance of records of assessment and collection of revenue, maintenance of stores accounts etc, still rest with the executive. This led to the division of responsibilities between the executive and the accounts organisation This gave rise to the unhealthy trend of shifting the responsibility on the part of both the executive and the accounts

For an ideal maintenance of accounts in its entirety by the accounts organisation, the following aspects require consideration.

(i) The executive should be completely relieved of their responsibilities for account keeping so as to enable them to concentrate on execution of works and deal with technical problems

(ii) The responsibility for maintenance of accounts of one or more divisions including initial accounts should be entrusted to an Accounts Officer centrally located He should be made responsible for the correct maintenance of accounts, accuracy of payments and be answerable to audit All audit notes and inspection reports issued by the Accountant-General should be replied by the Accounts Officer, if necessary in consultation with the executive on technical matters

(iii) In future accounting system, for taking quick decision, it is necessary that the accounts and engineering wings should work in perfect harmony with equal responsibility for the progress of work. The present system requires radical overhauling and has to follow the pattern of a combined Chiefs of Staff evolving a common military strategy

This system of accounting as adopted in Nagarjunasagar suffers from the inherent disadvantage of the fact that the executive has no power to pay. There were many instances where payments were held up, when emergent works had to be carried out and when interpretations could be made in the conditions laid down in tenders. The Accounts Officer goes strictly by the wording of the clause, but the spirit of the clause is ignored. In several cases this resulted in incorrect, delayed and less payments and contractors had ultimately to go for redressal to arbitrators and courts. This distrust between executive, contractor and paymaster caused undue inflation in the rates, as the contractors had to allow for such delays in the rate structure.

This defect in the accounting system was modified in subsequent projects such as Srisailam and Pochampad in Andhra Pradesh by placing the Deputy Chief Accounts officer under the administrative control of the Chief Engineer. The Deputy Chief Accounts Officer is designated as Director of Accounts. In this system, the Chief Engineer takes responsibility for delay in payments and passes orders on differences in interpretation of terms of contracts arising between the Division Office and the Pay and Accounts office. Thus, the advantage of cent per cent pre-audit and concurrent audit by the Accountant-general have been maintained intact, while the scope of delays inherent in the pre-audit system is eliminated. This system of accounting as revised is recommended for future projects.

TABLE 11.1

Bin Card particulars

Bin Card Number

Group :
Sub-Group :
Name :
Part No. :

Unit :
Maximum :
Minimum :

Cost Price :
Issue Rate :

Supplies Ordered			Collection		Stock position						
Purchase Order No. and date	Quantity	Delivery period	Date and Invoice ref	Quantity	Date	Receipt or issue ref.	From whom received or to whom issued	Receipts	Issues	Balance in hand	Remarks and initial
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)

Inventories : Date Count Date Count Date Count

CHAPTER XII

OUTSTANDING CONSTRUCTION FEATURES

This chapter deals with the outstanding construction features of the Nagarjunasagar dam. The main purpose of describing these events is to serve as an example and guide for future construction works so that the details of the work completed may be studied critically and improvements made in future dam building activities in India and abroad. Some important construction features of various works right from the early stages of construction, are detailed below :

Masonry Coffer Dam

12 2 The masonry coffer dam preceded all the important works in the Nagarjunasagar dam. It covered one-third the width of the river on the left flank to facilitate the progress of work in the river bed round the year. The coffer dam was 901 metres long and was aligned along the outcrops of rocks. On exposed rock, it was raised directly without further blasting or chiselling for keying or roughening. The work did not involve much dewatering The coffer dam is 1.8 metres at the top with a batter of 1 in 12 on the water face The airface is vertical to a height of 3 metres and sloped in a gradient of 0 67 : 1 (horizontal : vertical), thereafter.

12.3 The structure was built by collecting cobbles from the river bed and quartzite stones available at site within a distance of 2 50 km The masonry was built in random rubble in layers of 20 cm height. The first layer was placed in mortar of one part of cement and four parts of sand Before laying the masonry, the foundations were properly cleaned and a 25 mm. thick layer of mortar was laid. The rest of the masonry was built with mortar in the proportion of one cement and eight sand. The work was allotted to four job workers who made their own arrangements for supply of stones and sand. Diesel driven mixers of 0 4 cu m. capacity were used for mortar mixing At that time, electric power was not available at the site. Mortar was hand mixed, when the mixers failed or were not in adequate capacity The total quantity of masonry of the entire coffer dam was 59,900 cu m costing Rs. 1,560,000 It was completed on June 30, 1956

12 4 The outstanding features of this coffer dam are its speed, low cost and efficiency. It was built in a record time of 88 days. The unit cost of masonry with one cement and eight sand worked out to Rs 21 per cu. m which is the lowest rate of masonry of contemporary works

carried out in India. The coffer dam successfully withstood the extraordinary flood of 34,000 cumecs on September 30, 1964 without exhibiting even a hair crack or seepage.

Construction Sluices

12 5 The construction sluices were required to be provided in the dam for the diversion of summer flows of the order of 85 to 283 cumecs It was in 1963 that six diversion sluices of 3 05 m diameter were built with their centre level at 82.3 metres and 7.6 metres above the river bed level. This work presented very complicated problems in view of a large-scale work to be accomplished in a very short time and to be completed before the floods. No contractor came forward to take up the work as prompt action and enormous arrangements were necessary involving risks Therefore, the work had to be taken up departmentally; otherwise, it would have involved the loss of one working season. The engineers could not plan in advance, for, the designs were delayed due to the necessity of model studies and the river would not allow working in the bed beyond the middle of May, 1963 The work was started in the middle of March, 1963. The entire work had to be organised round the clock in three shifts, on a war footing.

A Record Progress

12 6 This colossal task of construction sluices involved 31,388 cu m of reinforced cement concrete work, 4,278 sq metres of shuttering and 850 tonnes of reinforcements The whole of this work, estimated to cost Rs 42 lakhs, was completed in 59 days before the arrival of floods. This was the biggest departmental work ever organised and completed in time by the project while racing against time. The unit cost of reinforced cement concrete work including cost of cement and steel came to Rs 135 per cu m. which was the lowest rate compared with similar works carried out at that time in the country

Conveyance of Rubble in Skips

12.7 Elaborate and detailed planning was necessary to collect, convey and feed the materials for putting up the massive masonry wedge of 5.76 million cubic metres across the river The quantity of masonry handled in constructing the dam was more than the quantity of the masonry of all the dams put together in Andhra Pradesh so far built. At the peak progress during construction, quantity as large as 1,500 wagon loads (metre gauge railway) equivalent to 15,000 tons of materials were handled per day. Maximum manpower was utilised with minimum mechanical equipment involving foreign exchange. In this process, the

collection, conveyance and supply of stones from quarries to the top of the dam for construction was a complicated and difficult task. The stones were mostly lifted manually through scaffoldings in the first stage of construction and monotower cranes utilised for lifting in the second stage and the stones were collected manually into skips of 4 25 cu. m. capacity, for feeding monotower cranes. Afterwards they were lifted by mobile cranes into lorries, the bodies of which were specially made to receive the skips. The lorries conveyed the stones to the dam for feeding the monotower cranes. This method was followed from 1960 to 1963. Later a novel and impressive method was adopted to eliminate mobile cranes for lifting and conveying the skips in lorries.

Novel Method for Rubble Feeding

12.8 This novel method involving gravity feed may be described in brief. An elevated platform of 2.4 metres high and 120 metres long was prepared just above the track level of hauling yard. The elevated platform was used as a dump yard for the stones. The railway track and the dump yard on the elevated platform were parallel. At the quarries, stones were loaded into the lorries manually. The stones brought from quarries in lorries were unloaded from the elevated platform directly into the skips mounted on flat trolleys travelling on the railway track at the lower elevation. Sometimes when the skips on trolleys were not readily available to receive the stones directly from lorries, the lorries dumped the stones on the elevated platform. Then the stones were manually rolled directly into the skips travelling on the railway line at the lower elevation. This method of gravity feed altogether eliminated mobile cranes at the stone quarries for rehandling the stone-filled skips from the ground in the lorries. This gravity feed effected a saving of Rs 5 25 per cu. metre and accelerated the progress by quick rehandling. This unique method is recommended for haulage and rehandling of stones for future masonry high dams. This arrangement was made both on the left and right flanks. The saving effected by this method was estimated to be in the order of Rs. one crore in the construction of the Nagarjunasagar dam.

Floating Batching Plants

12.9 At the initial stages of the project the lifting of materials for the construction of the dam was accomplished by scaffoldings and monotower cranes. Scaffoldings were erected to an elevation as high as 91 metres. Monotower cranes had the limitation of lifting over a height of 60 metres. As the dam went high, lifting materials by scaffoldings and shifting of monotower cranes to higher elevation became unavoidable.

12.10 With the rising of the dam, a high level water platform was available on the upstream side of the dam This was utilised with advantage for cutting the cost in leads and lifts of materials Rubble, concrete and mortar were conveyed from the foreshore of the lake in punts and were hauled by launches. On the foreshore, batching plants were erected on punts which travelled at higher elevations as the water in the lake rose. The materials from the shore brought in skips and buckets were hauled to the dam. The loads were partly picked up by monotower cranes. In blocks where there were no cranes, the materials were also lifted manually supported by scaffoldings This system worked out quite satisfactorily. But during the last days of May and June 1967 there were heavy gales with high velocities, due to which a heavy wave action developed and the work had to be suspended This method was adopted only for a limited period. With this method, considerable savings were effected in lift charges.

Highest Scaffoldings

12.11 Nagarjunasagar dam construction is an epic of human effort Manual labour was employed to the greatest extent In an underdeveloped country like India, mechanisation involves imports with scarce hard currency. Alternative methods, therefore, were adopted without foregoing efficiency or speed, with an additional advantage of maximum employment potential Machines were utilised to the extent they were available and various base lines of operation were laid as explained in Chapter V Lifting materials manually over a height of 91 metres for massive and colossal construction is the most interesting feature and a marvellous achievement in building this monumental structure The available local materials for scaffoldings were utilised from casuarina ballies (round posts) as props to bamboos for matting

The scaffolding consisted of a framework of casuarina ballies of 100 mm. diameter jointed with bolts of 12 mm diameter. The framework rested against the slope of the dam and was covered with bamboo matting At the platform level, the props of the casuarina framework were fixed into the ground with mortar The scaffolding went winding along the slopes of masonry along the air face of the dam. For scaffoldings over 15 metres height, anchor bars of 25 mm diameter were provided into the face of the dam to hold the scaffoldings The anchor bars were generally at 3 m intervals. Bolts and nuts were used for clamping the ballies in a gradient of 3 . 1 (3 horizontal: 1 vertical) for supporting the bamboo matting to make the walkway. The scaffoldings were 2.7 m. in width with a landing at every 3.3 m height. About 30,000 workers of various trades drawn from all parts of India participated in various sectors of operations, backed by an optimum combination of men and machinery. Thousands of men and women carried stones and mortar over

the scaffoldings like bees in a hive. The various integrated operations resulted in the unusually splendid record progress of 7236 cu. m (255,700 cubic feet) in a single day, on December 24, 1965. This extraordinary progress has no parallel in the history of construction of dams in the world.

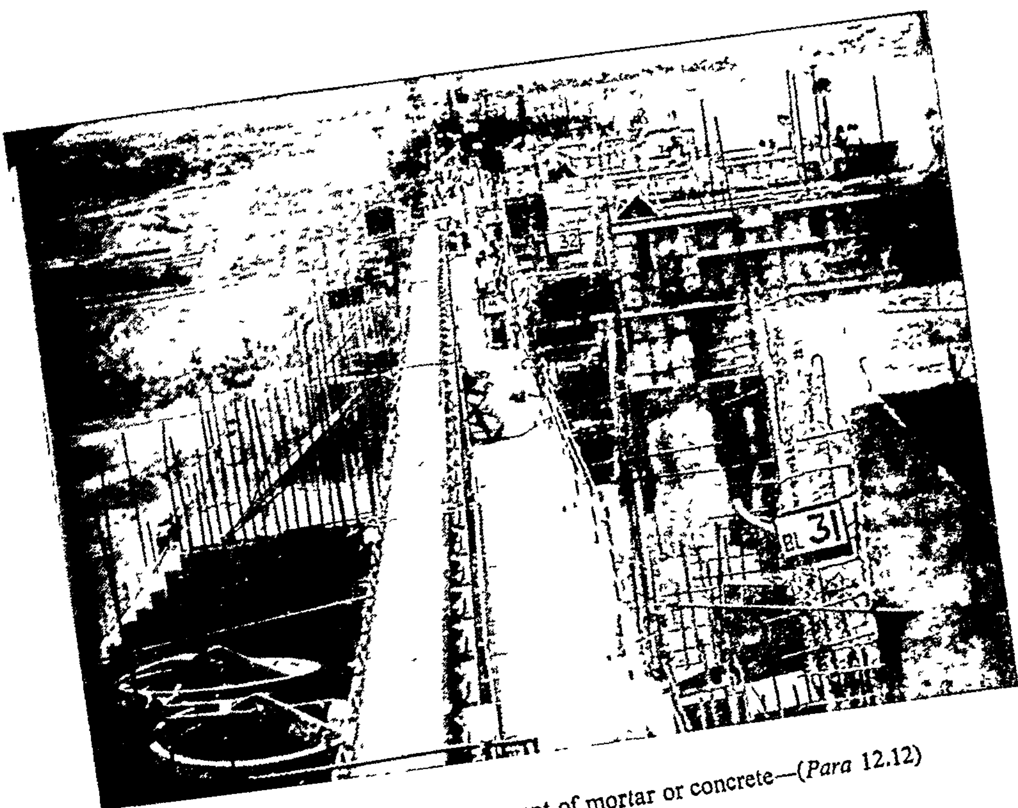
Conveyance of concrete by Belt Conveyors

12.12 For the conveyance of mortar and concrete, mostly indigenous methods of transhipment were employed. In the absence of aerial rope-ways and cranes on trestles which required to be imported, the problem was effectively solved by a system of belt conveyors. The width of the spillway is 471 metres. Belt conveyors were erected for feeding from both flanks of the spillway. Monotower cranes were available on the non-overflow portion of the dam for feeding the belt conveyors.

12.13 The belt conveyor system consisted of a 0.92 metre wide rubber belt moving on steel rollers mounted on steel trestles over the spillway. Taking off from non-overflow sections of the dam, the belt conveyor system was projected into the spillway. The distance covered from the left flank was 327 metres and from the right flank 342 metres At the feeding end of the belt conveyor system, the concrete or mortar in buckets was lifted by cranes and unloaded into hoppers. From the hoppers concrete or mortar was regulated over the belt conveyor by hand operated chutes At the supply end, the conveyors were provided with revolving hoppers, and elephant trunks, for delivery of the material into chutes radiating in different directions. From the main chute, the mortar or concrete was branched off in different directions by smaller chutes. This system of distribution is similar to the flow of water from canals into field channels. Whenever chutes could not directly dump the material, at the site of placement due to distance, the material was rehandled with manual labour With the raising of the spillway, the belt conveyors which were erected on angle iron columns were raised by welding extension pieces. With the raising of the spillway the trestle columns got buried in the concrete or masonry. Each belt conveyor could supply as much as 67 cu. m. of concrete or mortar per hour, but it was difficult to arrange for this progress continuously due to the time taken at the receiving end and the arrangements required for changing the chutes at the supply end Thus, the belt conveyor system can be effectively utilised for conveyance of mortar or concrete or metal for concrete except for stones of large size required for building masonry.

Walk-way across the Spillway

12.14 The spillway rose to a level of 169.5 metres in 1967. To complete the work as per the schedule, several materials had to be



Belt Conveyor for transhipment of mortar or concrete—(*Para* 12.12)

transhipped from the left to the right flank such as the embedded parts of crest gates, spillway bridge materials, spillway piers, reinforcements, air and water lines and miscellaneous articles. There was no facility for the conveyance of these materials across the overflowing spillway. At this stage for manual rehandling, a walkway of 1 8 metres (six feet) over trestles of 9.2 metres height was provided at a level of 176 9 metres, about a metre higher than the maximum expected flood level in the spillway for that season The walkway connected the left and the right flanks over a length of 471.2 metres With this arrangement the spillway piers could be raised to 176 9 metres level quickly for erecting the crest gates

12 15 The construction of the walkway was a difficult task It had to be built against gales and winds of high velocities. This intricate work which was most vital for the timely completion of the dam was accomplished in a record time of 45 days without a single accident. Mr. S S. Quadri, Assistant Engineer in-charge of the work was on duty in three shifts and was singly responsible for the timely completion of this work of complexity. But for the walkway, the entire programme of raising the spillway piers, crest gates, spillway bridge and connected works would have gone behind the schedule by one season This work has been highly appreciated and acclaimed as a great engineering feat by officials, the press and the public The Government congratulated the Engineers through All India Radio.

Economies Effected During Construction

12.16 Success in any job, especially the construction of a mammoth project like the Nagarjunasagar dam, mainly depends on the ability of the engineer in-charge, to plan properly, handling of men, material and machinery efficiently at the lowest possible cost Careful planning for construction by selecting suitable materials and equipment for each phase is of paramount importance. Such timely and advance planning naturally brings in large dividends, and economies can be effected in the project cost. It also results in greater speed and early benefits. Adequate controls in the shape of periodic report of progress and unit costs are also important.

12.17 Taking the overall picture of topography, availability of materials, necessary plant and machinery, projects are planned for the required benefits After taking up a project, the Construction Engineer has to analyse the factors, the actual field conditions and try to economise in various items. In this aspect, economies have been effected in the course of the execution of the project from time to time by the field engineers and this by itself is considered an outstanding contribution.

12 18 Economy in the course of construction of a dam can be mainly divided into three aspects i.e. the redesign and revision of specifications due to model studies, research work, and due to alterations during execution. The total economy thus effected came to Rs. 79 million on important items of work as detailed under :—

	Rs. in millions.
(i) *Economy in Redesign and Revision of Specifications.*	
(a) by proposing masonry dam instead of concrete.	40.000
(ii) *By Model Studies and Research Work.*	
(a) Spillway model studies . ..	1.100
(b) Redesign of Cement mixes	5.400
(c) Evolution of new type of air entraining agent.	0.125
(iii) *Economy Due to Alterations During Execution.*	
(a) Adopting lean mix of mortar above maximum water level of the reservoir ..	0.035
(b) Selection of suitable machinery and reducing foreign exchange	0.090
(c) Location of quarries nearby . ..	1.760
(d) Rail transhipment changed over to road .	8.400
(e) Rubble rehandling . ..	10.000
(f) Location of sand quarries nearby ..	0.250
(g) Departmental execution of construction sluices	3.200
(h) Change over from river sluices to diversion tunnel	6.800
(i) Change over from steel trestle bridge to masonry bridge .. .	1.200
(j) Gantry crane and floating batching plant	0 750
Total ..	Rs. 79.110 million.

The economies effected in various fields are described in detail below :

Economy in Design and Specifications

12.19 A major aspect of economy effected under the item of design and specifications was due to the decision to construct this high dam as an all-masonry dam unprecedented in the world This resulted in a major economy of Rs. forty million as per rates prevailing in 1955

and 1956 There was no precedent of constructing a masonry dam of 121 metre height. The advantages of masonry have been fully explained in Chapter VIII.

Economy Effected in Model Study and Research Work

12 20 Hydraulic model studies were conducted at Engineering Research Laboratories Hyderabad, to see to the structural safety of the various appurtenances of the dam, and also to see whether any economy could be effected. Also tests were made at the laboratory at the dam site to design the mortar mixes and test them

Spillway Model Studies

12.21 The radius of the flip bucket for the spillway originally provided by the Central Water and Power Commission was 27 metres As a result of detailed experiments at the Hydraulic Research Laboratories Hyderabad, it was found that there was a possibility of reducing the radius Extensive model studies showed that the bucket radius could be reduced to 21 metres with more efficient functioning of the bucket This proposal was accepted by the Central Water and Power Commission This modification was made during execution. This change resulted in a saving of Rs. 1.1 million at the prevailing rates of 1957-58

Redesign of Cement Concrete Mixtures

12.22 In the original design of concrete mixes, the quantity of cement per cubic metre was 196 kg As a result of experiments on different grading of aggregates for the concrete, conducted in the laboratory at the dam site, it was possible to reduce the cement content from 196 kg to 150 kg per cu.m. This resulted in a saving of Rs 1 4 million at the prevailing rates of 1957-58 Further, as a result of experiments, the cement content in the mortar mixes for masonry was also reduced by 6 50 kg per cu.m of masonry. This resulted in a saving of Rs 0 87 per cu.m. of masonry or about Rs. four million for the full quantity of masonry in the dam. Thus there was a total saving of Rs 1.4 + 4.0 = Rs 5.4 million.

Evolution of a New Type of Air Entraining Agent

12.23 Entrainment of air in concrete and mortar mixes greatly improves workability, reduces bleeding and segregation and facilitates the placing and handling of concrete Each one per cent of entrained air permits a reduction in mixing water from two to four per cent with some improvement in workability and neatness in the finish of the work. The

advantages of air entrainment are improvement of workability and durability, reduction of the permeability, decrease in bleeding and segregation, reduction in the heat of hydration, and reduction of the effects of freezing and thawing and reduction of the water content As air entraining agents, Viasol and Durex were the most commonly used, but these had to be imported. To obviate the difficulty in obtaining foreign exchange, attempts were made to manufacture an air entraining agent in our country for the first time in the Hirakud project This was named Aerosin. This Aerosin was used in the Nagarjunasagar dam initially for the first two years The contents of this aerosin were resin, caustic soda and glycerine Of these ingredients glycerine is the costliest item. Efforts were made to eliminate completely or to reduce the glycerine content in Aerosin. After a great deal of research in the laboratory, it was found that it was possible by a new process to eliminate the use of glycerine completely. The air entraining agent thus prepared with the modified process was found equally efficient and so this process was continued The new air entraining agent was termed Aerosin-M and was used till the completion of the dam The old aerosin with glycerine used to cost Rs. 0 80 per lb and the new product aerosin '*M*' cost Rs. 0 25 per lb. The total savings was Rs. 125,000.

Economy Due to Alterations

12 24 We now list the economies effected during execution without sacrifice of the quality and speed of construction

Adoption of Lean Mix

12 25 The Nagarjunasagar specifications laid down that the front face of the entire dam to a width of 2.7 metres should be constructed with the richer mix of one cement and three sand due to considerations of imperviousness The rich mix was proposed for the entire water face from foundation to the top reservoir level. Between the maximum water level and the top reservoir level, the rich mix (one cement, three sand) was considered superfluous and was changed to the lean mix of 1 cement and 4.72 sand Thus, the maximum water level being 181 metres, it was proposed to use the lean mix of 1 : 4.72 instead of 1 : 3 because the zone higher than 181 metre level would not come in contact with water. This proposal was later accepted by the Central Water and Power Commission This change during construction resulted in a saving Rs. 35,000. This saving would appear small for the Nagarjunasagar dam Similar savings effected for other dams in India and abroad would result in a massive figure.

Selection of Machinery and Reducing Foreign Exchange

12.26 In planning the Nagarjunasagar dam, great care was exercised to keep the foreign exchange requirements to the barest minimum. In selecting the machinery required, the aspect of economy was kept in view and the purchase of new machinery was avoided to the extent possible. Mostly the machinery used and found surplus in other completed irrigation projects in the country was indented and put to use. In this category the Washington and Clyde cranes, Winget and Blawknox batching plants which were brought from the Hirakud project may be mentioned. The batching plants were repaired and were used right till the completion of the dam. Even heavy earthmoving machinery like dumpers, dozers and shovels were brought from other completed projects in the country. Thus economy was observed in the procurement of machinery. The principle broadly adopted was a combination of the existing and available machinery and equipment in the country with maximum of human labour. This not only dispensed with costly machinery requiring scarce foreign exchange but also resulted in switching over to maximum utilisation of the enormous manpower in the country. The savings due to the procurement of surplus machinery from other river valley projects was of the order of Rs 90,000.

Location of Quarries

12 27 In the initial stage of construction, rubble was quarried mostly from the island quarry within a distance of two to three km, upstream of the dam. Later on, as the height of the dam increased, the island quarry got submerged gradually due to the formation of the reservoir thus necessitating the opening of new quarries On the left side of the river at a distance of 11 km. from the dam site granite quarries were operated as per original investigations. After thorough investigations subsequently, a quarry, 1½ km nearer, was investigated and found to yield all the stone required for further construction of the dam Thus, the saving due to decrease of lead by 1.6 km in a quantity of 2.5 million cubic metres of stone was Rs. 1 76 million.

Location of sand Quarries

12.28 After the construction of the high masonry coffer dam, a considerable quantity of 0 06 m. cu. metres of sand was deposited upstream of the river near the right bank above five 5 km from the dam site. There is no sand quarry on the right bank and therefore, this deposit was very handy An approach road was constructed along the right bank at a level of 91 metres, and the sand was collected and

used on the dam works on the right bank, thus, resulting in reducing the lead by six km effecting a saving of Rs. 0 25 million.

Rail Transhipment Changed Over to Road

12 29 The method of conveyance of rubble from the quarry to the dam site as originally thought of was by means of railway track, locos and skips. In view of the heavy cost of the railway line due to the difficult terrain, the method of transport of rubble was reconsidered As an alternative, the construction of a road with easy gradients was considered and the conveyance was proposed to be done by lorries. This road also served for the sand from the Halia river. The requirement of rubble per day was 3500 cu.m Conveyance by road adopted against conveyance by railway resulted in a saving of the capital expenditure of Rs. 8 4 million.

Rubble Handling

12.30 In the trestle stage of construction, rubble was proposed to be dumped in a rubble yard near Pylon This rubble was to be loaded into skips and rehandled on lorries by cranes and conveyed to the dam by lorries along the 128 metre level road to feed the monotower cranes. This proposal required a number of lorries and cranes. On re-examination it was found cheaper to convey the rubble by gravity—feeding the skips mounted on a narrow gauge trolley line from a high level platform This system of rehandling and conveyance dispensed with a number of trucks and cranes, resulting in a saving of Rs 10 million.

Departmental Execution of Construction Sluices

12.31 In the earlier stage of construction, six construction sluices of 2.70 metre dia. were located in the spillway with the centre line at 82 metre level capable of discharging 282 cumecs at six metre head According to the original proposal, these sluices, were to be plugged after the spillway was raised to 129 5 metre level when the low flows would pass through river sluices.

12 32 The construction of the six metre dia. construction sluices at 82 metre level costing Rs. 8.8 million was taken up departmentally and completed in a record time of 45 days, thus achieving indirect economy The unit rate of concrete worked out to Rs 135 per cu m Assuming departmental overhead charges at as much as 25 per cent, the unit rate would be Rs 135+34=169, say Rs 170 per cu.m. The contractors' tendered rate was not less than Rs 300. There was a saving of Rs 3.2 million.

It may be pertinent to examine here why departmental execution was not resorted to, for other works, when this method resulted in savings in construction cost Departmental execution was not possible because of meagre resources and the limited staff available.

12 33 In this connection, the author feels the pleasure of mentioning the names of the following outstanding Engineers who toiled day-in and day-out without regard to their health and personal comforts and convenience.

1. Mr. S. V. Sastry, Assistant Engineer
2. Mr. R Venkateshwara Rao, Assistant Engineer
3. Mr. T Raja Ram, Assistant Engineer
4. Mr Shujat Ali, Assistant Engineer
5. Mr M C V Raju, Assistant Engineer
6. Mr S K S Iyangar, Assistant Engineer
7. Mr. A V Subba Raju, Assistant Engineer
8. Mr. Narasimha Murthy, Junior Engineer and
9. Mr P Sreenivasulu, Junior Engineer

Changing Over From River Sluices to Diversion Tunnel

12 34 As per the previous design, river sluices were proposed at 129.6 metre level When these sluices were commissioned, construction sluices with centre line at 82 metre level were to be plugged at high heads It would have been very difficult and not desirable. It was, therefore, necessary to have outlets in the dam at a suitable level in between elevations 82 metres and 130 metres to facilitate the plugging of the 130 metre level sluices One of the proposals considered was to provide 18 sluices at 130 metre level and eight sluices at 102 metre level But the 102 metre level sluices would have to be constructed including installation of gates, by May 1964 and these sluice blocks had to be raised to a level of 142 metres by that time These sluices would have to be designed for operation with the full reservoir head of 79 metres.

12 35 Tenders were called for the river sluice gates Examination of the tenders revealed that the gates could be supplied only by the end of 1964 and as such this would not fit into the construction programme Further, as against a rate of Rs 16,140 per sq metre provided in the revised estimate for the river sluice gates, the lowest rate as per tenders was Rs 82,000 per sq metre At this rate for gates, the cost of the 26 river sluices worked out to Rs 20 million Further, the construction of 18 river sluices at 130 metre level would have to be done during the period January 1966 to June 1966 In this period the spillway had

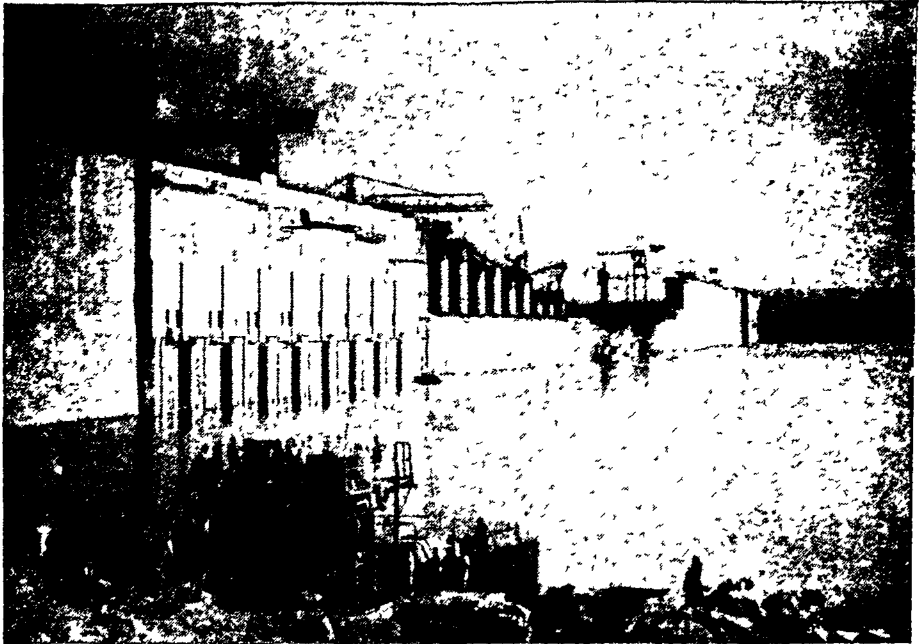
also to be raised by 30 metres, i.e., from 125 metre level to 155. This was not feasible and was likely to delay the completion of the dam.

12 36 Taking all these factors into consideration, it was felt that alternative arrangements to the river sluices were necessary. After a great deal of study, it was decided to dispense with the river sluices and to construct a 8.23 metres dia. horse-shoe tunnel which would be useful not only for river diversion but also for the supply of water for the irrigation of second crop for the Krishna delta situated 175 km. down below the dam. The proposal consisted of the construction of a diversion horse-shoe tunnel of 8 23 metres dia. with invert at the 91 metre level crossing underneath the left earth dam at 76 metres from the end of the masonry dam The ground level at the crossing is 163 metres and the granite rock is at a level of 128 metres The 91 metre level tunnel is entirely in granite and 790 metres long and was concrete lined. An intake structure was provided with two vents of 3 metres ×7.5 metres and fitted with gates. The tunnel would discharge 566 cumecs with a head of about 15 metres i e. with the reservoir level at 106 m The tunnel entry was plugged later on.

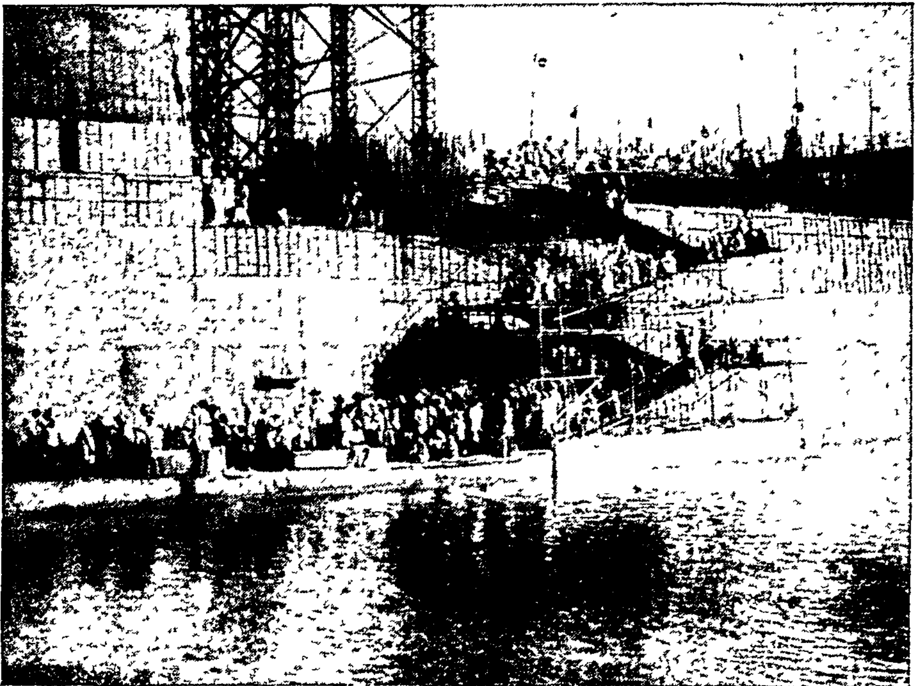
12 37 The 91 metres level tunnel could be made use of for regulating supplies of water to the Krishna delta, instead of constructing 18 permanent river sluices in the spillway with the centre line at a level of 130 metres. With this in view it was proposed to construct another horse-shoe inclined tunnel of 8.23 metre dia. with the invert at 122 metre level connected with the 91 metre level tunnel The total length of this connecting tunnel is 96 metres. The inclined tunnel is in quartzites and was lined to the finished dia of 8.23 metres. The 122 metre level tunnel was developed with intake structure in front with two vents of 3 m. × 7.5 m. operating against a head of 61 metres. The discharge from the tunnel was let into the river through an exit channel. This decision, effecting a saving of Rs. 6 8 million, dispensed with the river sluices. This change proved to be a happy one as it resulted in indirect economy by facilitating quick progress to the extent of reducing the construction period by one season The resulting saving due to the completion of an irrigation structure by one season ahead of schedule could well be imagined by the increased output of foodgrains by early release of the waters for the crops and the reduced establishment and other expenditure during one season.

Change Over From Steel Trestle Bridge to Masonry Ledge

12.38 In the pre-trestle stage, the lift involved for construction materials was only 32 metres, which is not very high. Masonry in this portion was done by lifting materials with Washington and Clyde cranes



View of Floating Batching Plant (*Para* 12 39)



Placement of concrete from water side, block 42 from floating platform—(*Para* 12.39)

erected on an earthen platform at a level of 83 metres supplemented by manual labour without the use of heavy equipment on a large scale. The second stage of work upto the top of the dam at a level of 184 metres known as the 'trestle stage' required a lift of 110 metres. For this, it was proposed to construct a steel trestle bridge of 10 5 metre width for a length of 1091 metres along the dam at a cost of Rs. 9.4 million. The steel required for this trestle bridge was 10,000 tons It was difficult to procure this quantity of steel in the country and some quantity had to be imported. These proposals involved undue delay After a great deal of thinking and study of alternatives, it was decided to construct a masonry ledge of 7.35 metre width in the left and right non-overflow portions of the dam at an elevation of 128 metres and limit the length of the trestle bridge to 128 metres and width to 7.35 metres in the spillway portion against 1091 metres long and 10 5 metres wide as per previous proposals The trestle was, therefore, laid upto 128 metres in spillway blocks 25 to 36 at a cost of Rs. 3.1 million. The quantity of steel required for this was only 1870 tons. Thus the quantity of steel required was reduced from 10,000 tons to 1,870 tons.

The new proposal of constructing masonry ledges at a level of 128 metres on left and right non-overflow sections and laying a trestle bridge of 128 metre length on the spillway were, therefore, adopted. Later the length of the trestle bridge was further reduced from 128 metres to 116 involving only about 900 tons of steel. The balance of the spillway portion was constructed by manual labour with timber scaffoldings. The difference in cost between the original proposal and the revised proposal amounted to Rs 1.2 million representing the savings effected.

Gantry Crane and Floating Batching Plant

12.39 During 1966-67 and 1967-68 a novel method of supplying mortar to the blocks from the upstream of the reservoir was adopted. A gantry crane was erected in block 42 The crane was fabricated with available materials. Mortar buckets were taken near the gantry crane in the reservoir on punts. The gantry crane lifted the buckets from the punts and fed them on to the blocks. Since the reservoir water level was very high compared to the downstream platform, there were adequate savings in the lift charges. The gantry crane erected in block 42 supplied mortar and concrete for blocks, 41, 42, and 43. Thus by providing a gantry crane in block 42 for concreting the spillway crest and piers, in block 41 and 43 the payment of huge amounts towards lift charges by scaffolding was obviated. With gantry cranes a manual lift of 45 metres was saved for a quantity of 473 cu. m. of concrete. The amount saved by providing gantry crane was Rs. 0.25 million and Rs 0.50 million by floating batching plants, totalling Rs. 0.75 million.

12.40 *Miscellaneous Savings*

As already mentioned, the methods adopted for construction of this dam were not restricted to any particular system rigidly. Due to the site conditions and with availability of men and materials, these methods were changed whenever found convenient, the object being facility in work and speed in completion of the dam. A particular method may at first appear to cost more but it may at the same time facilitate increased output, thereby completing the work earlier, resulting in indirect economy. Quarrying rubble departmentally, crushing aggregate in the departmental crushing plant and conveying sand departmentally, come in this category. In the case of crushing aggregate by departmenal crushers, it was seen that the unit rate of this aggregate cost more than that supplied by the contractor. But at the same time it was a fact that the departmental manufacture of aggregate induced the contractor to quote less for aggregate. Otherwise, the department would have paid more if it had to depend only on the contractor's supply for aggregate.

12.41 In the construction of the dam, no major civil contract was awarded except for the tunnel work. The masonry work was given to more than twenty contractors on the piece work system. Annual tenders were called for and bargains made even with the lowest tenderer and a uniform rate for all the items was paid to all the contractors. Depending upon the exigency of the progress, the Chief Engineer was authorised to award the piecework, on nomination to any resourceful contractor.

12.42 Mortar and concrete were supplied departmentally to various blocks This eliminated work being awarded to big firms whose rates generally were at least 25 per cent above the rates tendered by petty contractors who could be assisted departmentally for machinery and other resources.

12.43 The job work system also resulted in the completion of the work economically. After getting quotations from all the job workers or Labour Mukhaddams (Petty Contractors), they were called for negotiations. In this, the Mukhaddams further reduced their rates. The lowest accepted rate was offered to all the other Mukhaddams and the work distributed to all of them. Thus the work was done quickly at reduced rates. This system was adopted particularly in road work and quarrying rubble, loading sand into lorries etc. Considerable economy was effected by adopting this method, since the rates were very competitive and reasonable and the work at the same time was got done earlier than one could expect from a big contractor.

12 44 Even in the construction of residential and non-residential buildings, economy was observed. The cost of cement which had previously been Rs. 67 50 per ton ex-factory was increased to Rs 102 50 per ton ex-destination. Though this increase resulted in an increase in the cost of buildings, care was taken to minimise the extent of increase with the use of lime mortar instead of cement mortar. Further in the case of residential buildings, to keep within the estimates, the plinth areas were substantially reduced. The higher type of buildings of the Chief Engineer and Superintending Engineer were given up and they were given the quarters of Executive Engineer only. To cut down the rates, negotiations were made even with the lowest tenderers.

12 45 For the construction of the dam and the canals, nearly 0 91 million tons of cement were required and the major supplier, the new cement factory at Macherla had commenced production Under the agreement negotiated with the company and as approved by the State Trading Corporation, the project got a rebate of Rs 7 per ton on the State Trading Corporation pool price. This alone meant a saving of Rs. 6 132 million for the entire project.

12 46 The above savings have not been included in the total savings effected in the project. There were many other economies, such as in the purchase of materials, bargaining with the contractors who had tendered lowest rates and in many similar items. In general the engineer has to be vigilant at every purchase and adopt every possible method of construction and to ensure overall economy in the construction.

RESUME

12 47 In conclusion, it can be stated that economy was the primary object at every stage from design and planning, to the execution of Nagarjunasagar. The planning of this dam was not rigid Flexibility was adopted for the harmonious synchronisation of the available men, material, machinery and money to achieve speedy execution at minimum cost.

A special feature of this project was the co-ordination achieved not only in the execution of the canals along with the dam but also in the development of the ayacut, making the fields ready to receive the water as and when the reservoir was able to supply it

An outstanding construction feature which surpasses all the economies effected by various methods was the planning of the project by methods of labour orientation This solved the unemployment problem for 30,000 workers in the dam organisation and more than this number in the canal system While providing mass employment, the method of construction utilised indigenous machinery and reduced dependence on costly imported equipment,

CHAPTER XIII

PROJECT AMENITIES

Irrigation and hydro power projects are generally in out of the way places. So adequate arrangements are necessary for the construction of new townships. The Nagarjunasagar dam construction at its peak progress required as many as 30,000 workers in the field. Including families, shopkeepers etc., the maximum population recorded was 72,500. For housing, new townships had to be built. This population was housed in five colonies :

Pylon Colony on the left bank of the dam site.

Hill Colony 6 Km north of the dam site.

Bandala Karva quarry camp, 10 km. to the north of the dam.

Right Bank Colony to the right of the dam site.

Lankamote Labour Colony 3 km. to the south-east of the dam site.

Labour Camp at Nagarjunakonda quarries——11 km to the south-west of the dam site.

Pylon and Hill colonies were named Vijayapuri North, while Right Bank and Lankamote labour Colonies were named as Vijayapuri South. Vijayapuri was the ancient name of the city situated on the left and right banks of the Krishna, which went under submergence with the formation of Nagarjunasagar.

13.2 In the order of their importance, the minimum facilities required for a project of this magnitude are—housing and roads, water supply and sanitation, medical and public health, electric power, education for children and workers, shopping centres, police stations and law and order, telephones, public relations, fire brigade and recreation centres.

13 3 The arrangements made for these facilities are briefly described in this chapter so that it might be a guide for other projects when taken up.

Housing and Roads

13 4 Housing requires careful study. Housing for the engineers and workers was planned as near to the work site as possible, preferably within walking distance and beyond store yards and batching plants. The labour colonies were located very near to the work areas and near to the quarry

camps and beyond the blasting zones At the investigation stages, it became inevitable to erect tents and temporary structures These structures were also necessary before launching a construction programme for the colonies.

13.5 The houses were designed partly as permanent structures, partly as semi-permanent and partly as purely temporary. At the completion of the project, the population was reduced to a great extent But some staff would be necessary for the maintenance of the project. For such staff it was necessary to build permanent structures

13 6 At the completion of the project some connected industries, educational institutions and cottage industries were expected to develop. We could not correctly assess their needs Semi-permanent structures had to be designed which, with some modifications, could be converted, if necessary, to permanent structures For workers and labourers who had to live close to the project, houses were designed purely on a temporary basis The roofs, doors and windows and other materials of these temporary houses could be dismantled and reused in other projects

Camp Buildings

13.7 Various kinds of houses were built for staff for residential purposes. As fixed by the Control Board, the following plinth areas and monetary limits for different types of buildings were adopted :—

Type of Quarter	*Plinth area Sq. Metre*	*Cost* Rs
Chief Engineer . .	279	30,000
Superintending Engineers	209	22,500
Executive Engineers .	167	16,200
Assistant Engineers .	137	12,000
A type Quarters . .	91	7,000
B type Quarters . .	61	4,500
C type Quarters	36	1,700
D type Quarters .	28	1,350

13 8 It was considered that hostel type accommodation should be provided for bachelors with a canteen Accordingly, a forty-roomed building named Project House was built. Each room had a bath room Incidentally this building also served for accommodating visitors to the project Each room was furnished with two beds. A rent of two rupees

was charged per day for ground floor quarters and three rupees for first floor quarters. No rent was charged for departmental personnel staying in project house until they were allotted quarters. This building was inaugurated by the late Mr J. V. Narasinga Rao, the then Minister for Public Works Department, Andhra Pradesh on December 11, 1958.

13.9 The Chief Engineer's quarter was constructed on the bank of the Krishna one kilometre away from the dam over-looking the entire construction work in the gorge. Other buildings were constructed in Pylon, Right Bank and Hill Colony and Bandala Karva

13.10 In the first year of construction, nearly 1,000 quarters were started, including 800 labour hutments At the close of the project 4,632 buildings were constructed as per details given under :—

Chief Engineer's quarter	1
Superintending Engineer and Executive Engineer type quarters . ..	35
Assistant Engineer type quarters .. .	98
A type quarters	305
B type quarters	937
B-II type quarters	209
C type quarters	360
D type quarters	186
E type quarters	1753
Temporary quarters	548
Non-residential quarters and Miscellaneous ..	201
Total ..	4633

13.11 The non-residential quarters include five guest houses, two central offices, two hospitals and three recreation centres. The names of the guest houses are—Vijaya Vihar, Tourist Annexe, Project House, Sethu Sadan, River View and Lake View. These were built by the Government. Apart from this, the number of the structures constructed by contractors for themselves and huts for their labour is about 8,000.

13.12 The buildings and roads were under a single Executive Engineer The roads connecting the housing colonies were mostly dust proofed with asphalt. The haul roads which were subjected to traffic by crawler tractors were left without dust-proofing as asphalt cannot withstand the strain. These roads during working season were watered with tracto-tankers. Thus the dust nuisance was overcome on all the project roads.

Water Supply and Sanitation

13 13 For drinking purposes and also for the construction, the Krishna River was the only source of water supply The supplies were pumped from it, in multi stages.

13 14 For construction purposes, storage reservoirs were built near the dam and close to the batching plants Highly turbid water during monsoons was coagulated with alum, settled and supplied. It was observed that the labour working on the dam had immediate access to the water pipes used for curing and were drinking this water. So it became essential to sterilise the construction water also with chlorination, though this was not required for curing and batching.

13 15 For drinking water supplies, elaborate arrangements had to be made by constructing intake structures in the bed of the river and water had to be purified through gravity mechanical filters and then supplied after chlorination through a network of pipe lines. With the rising of the water level in the reservoir, advantage was taken to reduce the pumping head by providing intakes At a level of 149 metres, two outlet pipes were provided, one on the right flank of the dam and one on the left flank The required water could be supplied by gravity through these pipes of 0.6 metre diameter. The outlet pipes were provided with sluice valves and the inlet of these pipes also was controlled with a gate to facilitate repairs to the sluice valves, if necessary.

13.16 The maximum quantity of water pumped per day during peak period of construction was .—

	Million litres
For construction purposes	1 80
For drinking water	2 25
Total ..	4.05

An Assistant Engineer was completely in-charge of the water supply arrangements with necessary supervisors, operators and other staff

13 17 Quarters of the staff were mostly served with underground sewerage, the treatment of which was effected with sceptic tanks built outside the inhabited areas The effluent after digestion was utilised for irrigation

Medical and Public Health

13.18 When the investigation division of the dam started the construction of approach road from Peddavura to the dam site, about 5,000

workers were employed No medical facilities were available in the camp. The District Medical Officer when approached, expressed his inability, as there was no provision in his budget for the newly started project The project authorities were requested to supply medical aid. The case was being examined Meanwhile, severe malaria broke out A doctor was appointed on nominal muster rolls and the problem was effectively solved Later, when the dam construction started, Dr. P Rami Reddy, Civil Surgeon, who was the first doctor to be appointed, opened a hospital in the labour colony in hutments. Due to inadequate protected water supply arrangements, there was a severe outbreak of cholera in January, 1957 and hundreds of workers were affected. Nearly 70 persons passed away. The hospital played an effective role in bringing the epidemic under control In 1957, a 50-bedded hospital was started in the Hill Colony On its completion, it was opened on December 11, 1958 by the then P.W.D. Minister late Mr. J V. Narasinga Rao.

13.19 As the activities of the project grew, a separate public health unit was opened. It was headed by a Public Health Officer in the grade of a Civil Surgeon Dr. Kache was the first Public Health Officer. He was assisted by two junior doctors and other staff. They were in-charge not only of the dam organisation but also of the canals. As the activities and the population at the dam increased, the number of beds in the hospital was increased to 120. The hospital was named Kamala Nehru Hospital, and it was declared open by Mrs. Indira Gandhi on December 6, 1963 Later on a twenty-bed children's ward built by Mr. V. Nageshwar Rao, was added to the hospital. It was opened on July 15, 1967 by Mr Morarji Desai, the then Deputy Prime Minister of India. The Children's Hospital was built with the effective co-operation and public donations collected by the President of Ladies Club, Mrs. Leela Ranganatha Swami, the wife of Mr. Ranganatha Swami, Chief Engineer. It was named Vijaya Laxmi Children's Ward This institution cherishes the memory of the great lady, who took active interest in children's welfare and passed away at the dam site in 1966.

13 20 In 1968, when the activity of the dam construction was reduced, the public health organisation was curtailed by abolishing the post of Public Health Officers and it was attached to the District Medical Officer.

13 21 Though the dam activity was reduced to a great extent in 1968, the work in the hospital and the number of patients did not decrease The hospital grew in the bed strength from 40 in 1958 to 120 in 1963 It was provided with a modern X-ray plant, E.C.G , short-wave therapy, an air-conditioned operation theatre, a blood bank and other laboratory facilities on par with a district headquarters hospital.

13 22 In 1963, when the hospital had grown, it was manned by a Superintendent, who was a surgical specialist, assisted by six Assistant Surgeons and three lady Assistant Surgeons, including one for family planning. In addition to the above staff at the Kamala Nehru Hospital situated in Hill Colony, there were three out-patient dispensaries, one at Pylon Colony, the second at Right Bank and the third at Bandala Karva quarry camp. There was a Civil Assistant Surgeon in each dispensary, except for the Right Bank dispensary, where there were two doctors, one male and the other female. The Nagarjunakonda Museum Colony and the Anupu labour colonies were served with a mobile dispensary

13 23 An isolation hospital with 12 beds was finally added to the Kamala Nehru Hospital. The hospital, with its attached dispensaries, catered to the needs of 1,200 out-patients daily and about 40,000 in-patients annually The children's attendance was about 200 out-patients daily and 8,000 in-patients annually. The hospital played a prominent role in treating the patients, especially in accident cases during the construction period.

Electric Power

13.24 Electric power plays an eminent role by making modern living comfortable and attractive. It was profusely used for lighting the colonies and for providing modern amenities to the residents The history of construction power in the project started with a 4 KW. Diesel generator installed in a temporary shed on the left bank of the river. Later, a 75 KW. set replaced it. This was followed by Diesel power from Macherla from a distance of 11 Km through a 11 KV feeder line. This power line was drawn from the Macherla Diesel power house with an aggregate installed capacity of 2200 KW In 1957, the power supply was established by extending Machkund hydro electric power supply by laying a 66 KV. line fron Tadapalli to Macherla, a distance of 115 km. To meet power failures and as a stand-by, two 620 KW. Diesel sets were installed on the right bank in July, 1959

13.25 In the early stages of the project, the entire spade work and laying of the transmission lines and transformers were done by Mr. V. S. Ganapathy Ram, Executive Engineer, under the directions of Mr. P. T. Malla Reddy, Superintending Engineer. Thereafter from 1965 onwards Mr. Misbahuddin Khan, Executive Engineer, ably managed the electrical division, assisted by five sub-divisions, in the peak period of construction. With the reduction of work from 1968, the number of sub-divisions was reduced to two.

13 26 At the peak construction time, the peak consumption of power per month was two million units (KW. Hrs.), costing Rs. 0 15 million

per month The maximum power load was 4700 KV.A. as against 2200 KV.A. in 1960. Of the 4700 KV A, maximum demand, 400 KV.A. was for lighting, 1200 KV.A. for residential and non-residential buildings and 3,100 KV.A. for construction purposes, for the batching plants and the 16 mono-tower cranes. The Andhra Pradesh State Electricity Board, from which the construction power was purchased, erected in 1958 a sub-station on the right bank with two 3000 KV.A. and one 1500 KV.A. 33/11 KV. step down transformers with the necessary controlling and metering equipment. A net work of 11 KV. and low tension lines, totalling about 70 Km and 125 Km. respectively was laid in the dam area and colonies. There were 70 transformer stations of different capacities varying from 100 KV.A. to 1000 KV.A. The canal campus in the vicinity of the dam area also was served by this net work of transmission lines.

13.27 The total number of street lights was 3000 of which one-fifth were fluorescent fittings and about 100 mercury vapour lamps The entire work areas in colonies were fully lighted to enable the work to go on round the clock.

Education for Children and Workers

13.28 With the commencement of the construction work, educational facilities started with two primary schools, one on the right bank and one in the Pylon Colony. The District Educational Officer, Nalgonda opened a primary school in the labour colony on the left bank which got submerged with the rising of the lake.

13.29 Later, one high school was opened in the Hill Colony and a middle school in the right bank by the project authorities. The high school started functioning from September 1957 under the headmastership of Mr. T. Surya Prakasham. The headmaster was vested with supervisory powers over all the primary schools at the dam site. With the increase in population, the demand for more schools arose in all the colonies.

Consequently, a primary school was started in the Hill Colony and another in the canal campus of the township. With the gradual rise of the school-going children in the right bank, a middle school was started there in 1962 and it gradually developed into a full-fledged high school with N.C C. facilities Thus, the minimum facilities for the primary and secondary education were provided. There came a demand for pre-primary education for children in the age group three to five years. A kinder-garten school was started in 1958 in the Hill Colony and it was later handed over to a Roman Catholic Mission, which later started convent schools in the Hill Colony and on the right bank. This ultimately developed into a girls' high school. It was inaugurated by Mrs. Indira Gandhi on December 6, 1963. The Educational Inspectorate adjudged the

schools in the dam area the best in the District of Nalgonda The high school in the Hill Colony achieved cent per cent eligibility in the Secondary School Leaving Certificate public examination results of 1966 This high school was later on converted into a junior college in 1969 At the peak of the construction activity, the total strength of the pupils in all the schools put together at the dam area was about 4,500

Free Labour Night Schools

13 30 While children's education in the dam was excellent, the officers did not feel content without the facilities in the township for adult education for labour. Many children of school going age between 12 and 18 were forced to work for their livelihood in day time Further, there were many adults who were not at all educated For the benefit of these people, the author started a night school The first school was started in a shed with the staff who volunteered to serve without any remuneration. It worked from 7 p m to 8 p m Later another night school was also opened in the right bank labour colony. Education was given upto the fifth standard The total strength of the pupils of the night school was 720 The education was in the mother tongue of labour, Telugu and Tamil These labour night schools did not take any aid from the project or the Government It was run exclusively on the philanthropy of the officers and contractors , Mr P R G Reddy, Executive Engineer, quarries and Mr G K Reddy, Executive Engineer, Mechanical gave Rs 50 each. This school was inspected by the Raja of Muktyala, the late Mr V. R. G K M Prasad, who admired the social activities of the officers and gave a donation of Rs 500 for dresses for 36 orphan boys. These children worked in the day-time and studied in the night schools. Mr M Tirpath Reddy, Assistant Engineer, took keen interest in these schools He organised a matinee cinema show in aid of the school which fetched Rs. 800 with kind help given by Late Mr Narsimha Reddy.

13.31 The night school had a salutary effect in developing the moral character of young workers. They became active volunteers in promoting prohibition and controlling unsocial activities among labour The night school education was based on fundamental principles of equality and brotherhood.

13 32 With the submergence of the labour colony, the left bank night school was shifted to the Pylon labour colony, where labour had shifted This colony also was submerged after four years. With the dwindling of construction activities and shifting of labour to other projects, the Pylon Colony labour night school was closed. The labour

shifted to the Sagar camp on the Right Bank. The Right Bank labour night school continued until the completion of the dam. Mr. M. Sree Rami Reddy, Executive Engineer took the initiative in running this charity institution. Among the contractors, Mr. A. Anantharaman gave a donation of Rs. 200 for running this night school and Mr. Ramakoteshwar Rao gave Rs. 50. Later, in the same building in 1966, a Government day school for giving primary education was started with free mid-day meal provision for 150 labour children and continued as one of the best schools on the Right Bank.

Technical Education

13.33 Right from the inception of the project, the Central Water and Power Commission, Government of India, started a technical school at the project to give mechanical training for the operations of heavy machinery. The first Deputy Director of this school was Mr. Naphray in the year 1957. The U.S. Technical Co-operation Mission deputed Mr. Strobel for the training The school, which was opened in 1956, on the left bank, was shifted permanently to Right Bank in 1958. This school imparted practical training to operators for running and maintaining earth moving machinery. The mechanics, after training, got employment in river valley and other projects all over India and abroad.

Teachers' Training and Engineering Colleges

13.34 At the completion of the project, several buildings became vacant. The laboratory of the project in the Pylon Colony and the store sheds were converted to teachers' training school. Mr. P. V. Narasimha Rao, the then Minister for Education, Andhra Pradesh, inaugurated a college of education in this campus on November 15, 1969. This college is now training the teachers required for schools in the State An Engineering College, named Nagarjuna Engineering College, was proposed in the vacant building of the Hill Colony by building additional accommodation for administrative buildings and workshops. This college was temporarily started at Hyderabad to be shifted to the dam site on the completion of the workshops.

13 35 In this connection it may be mentioned that the dam area was illustrious in ancient times due to the University of Nagarjuna in the second century A.D. during the reign of the Ikshvakus. The university area went under submergence. In modern times the ancient Educational activities have been revived with the construction of the Nagarjunasagar dam.

Shopping Centres

13.36 In 1956, with the construction activity of the dam increasing in the Pylon area, about 30 shops were started in hutments. A building of

the State Bank was erected later. Subsequently, in 1957 the department constructed nearly 100 shops in the Pylon Bazaar with stone walls and asbestos sheet roofing. With the increase in the construction activity, shops also sprung up in the Right Bank, Hill Colony and in the Bandala Karva quarry Camp The departmental shops were designed as residential The shop keeper was provided with family accommodation in the rear of the shop.

13.37 To check the prices and quality of consumer goods and food-grains, a co-operative society was started with a membership share of ten rupees. By 1960 this became a big organisation With a subscribed capital of Rs 50,000 the Government gave a subsidy of one lakh Rupees and free transport for food grains. In the final stage of construction, the name of the co-operative society was changed to Sangha Mitra (friend of society) The Sangha Mitra was housed in the sheds formerly built for officers.

Police Stations and Law and Order

13.38 The first police station was built in 1956 in the labour colony with walls of bamboo matting and asbestos sheet roofing in which a room with brick walls and an iron door was provided to serve as a lock-up.

13 39 With the increase in the labour population, several labour unions sprang up. With the construction activity growing, law and order problems became increasingly difficult in view of frequent clashes among various labour groups who came from different districts with different languages and were addicted to liquor and intoxicants In 1957 there was a major clash between the labour of Mahboobnagar District speaking Telugu and the Labour of Coimbatore district of Tamilnadu, speaking Tamil This practically led to a civil war The Mahboobnagar labourers (called Palamoor labour) took possession of the Left Bank labour camp In the clash, serious injuries were inflicted. There were clashes throughout the night and by dawn the Coimbatore labourers had to cross the river to save the lives of women and children. They took shelter on the right bank. While crossing the river, two persons were washed away. There were only six police constables to control a mob of nearly 9,000 The police force from Nalgonda district came late in the evening The author had to face the problems along with some volunteers by going into the colonies to stop the clashes and admit the injured into hospital This episode opened the eyes of the authorities and a permanent armed police unit of 200 persons was housed in the Pylon area with out-posts in all the colonies.

13 40 The police were provided with a wireless equipment. The organisation was headed by a Deputy Superintendent of Police, a Circle Inspector, two Sub-Inspectors and a Vigilance Squad assisted by necessary staff.

Telephones

13.41 Telephones are essential for running a project of this magnitude efficiently. The first telephone system was installed in 1956 by Mr. V. S. Ganapathy Ram, Executive Engineer, with a manually operated system Later a 25 capacity automatic exchange was installed in the Pylon Colony; subsequently another manually operated exchange with a capacity of 100 was opened in the Hill Colony. These telephones were considered insufficient to control the operations of the quarries, batching plants and for contacting officers. So it became necessary to give double and treble parallel connections. This system was meant to meet the internal necessities within the project area. Apart from this, trunk telephone connections were given to controlling officers including, Executive Engineers at their offices and residences The total number of local and trunk telephone connections in the project was over 300.

13.42 Apart from this, it became necessary to control the operation of batching plants and other installations which became remote due to the snapping of the bridge connecting the left and right banks of the river and also the Nagarjunakonda Museum and colony which was cut off after water rise in the Nagarjunasagar lake. To overcome this difficulty, four wireless transmitters were purchased, two of 10 km. range and two of 32 km. range. These sets were of immense utility in the execution of the project.

Public Relations

13 43 In a project of this gigantic magnitude, public relations take a conspicuous place to educate workers, the visitors and masses. Mr. Y. Rama Rao was the first Public Relations Officer. He continued from the beginning of the project till its completion. He played an active role in building up this organisation from a scratch. At first this organisation was attached to the Superintending Engineer, Inspection and Control In 1969, it became independent at the completion of the project and was merged with the department of Information and Public Relations of the Government of Andhra Pradesh.

13.44 The public relations organisation was in-charge of all the guest houses for visitors and the community centres and collected infor-

mation from various sections for publicity of the various activities This section slowly developed into a big organisation. Two assistant Public Relations Officers of gazetted rank were added with the necessary staff. They were given a publicity van to educate the cultivators of the ayacut in agricultural operations and to train them in modern techniques of agriculture They organised several benefit shows in the dam area and in the ayacut.

The Public Relations Officer was made responsible for providing accommodation for visiting officers and the general public.

Fire Brigade

13 45 A fire brigade was installed in the Pylon Colony with a fire officer and necessary staff. The brigade had two fire engines with necessary equipment In view of many thatched labour hutments and other buildings, frequently catching fire in summer, the fire brigade did yeoman service to the project. It served not only the project camps but also the adjoining villages whenever there was a fire. The fire brigade establishment was borrowed from the State and financed by the dam organisation The fire brigade was also employed on a few occasions when there was a water supply break down for curing the masonry of the dam

Recreation Centres

13.46 Recreation centres form an important part of a project. The main recreation centres are cinema theatres. In 1956 a cinema theatre Narasimha Talkies was built in the dam labour colony by Mr. G. Limba Reddy. It served the project for four years With the area getting submerged with the rise of water in the reservoir, the theatre was shifted to the Pylon Colony There were three more theatres, one in the Hill Colony, and two in the Right Bank With the completion of the project in 1968 and shifting of labour and reduction in the staff, the two theatres on the right bank were closed The Narasimha Talkies in the Pylon Colony and the Krishna Talkies in the Hill Colony conitnued even after the completion of the project.

13 47 For recreation purposes, the department constructed two community centres in the Pylon Colony and in the right bank. There, dramas were staged by the work-charged employees and labour. Burra kathas (dramatic recitations) were given They were liked by the labour. Dances and dramas were organised by labour Some of these functions were filmed by the project authorities and were shown to labour.

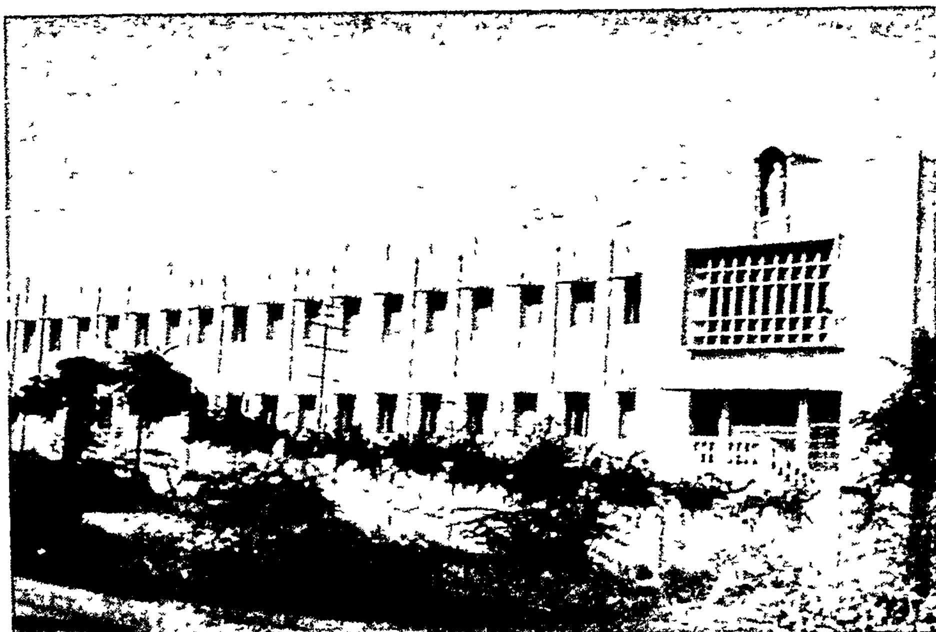
Annual social functions and festivals were celebrated such as Independence day, Dasara, Dipavali, Ramzan, Id-ul-zuha, Christmas etc. Special functions were held and dramas were enacted for recreation and

for collection of funds for charities and construction of temples, mosques and churches and for helping the destitute and orphans. Parents' Days were organised, when children enacted dramas and participated in fancy dress competitions. Monotony of construction life was punctuated by recreation and gave opportunity for young boys and girls for expression of their latent talents.

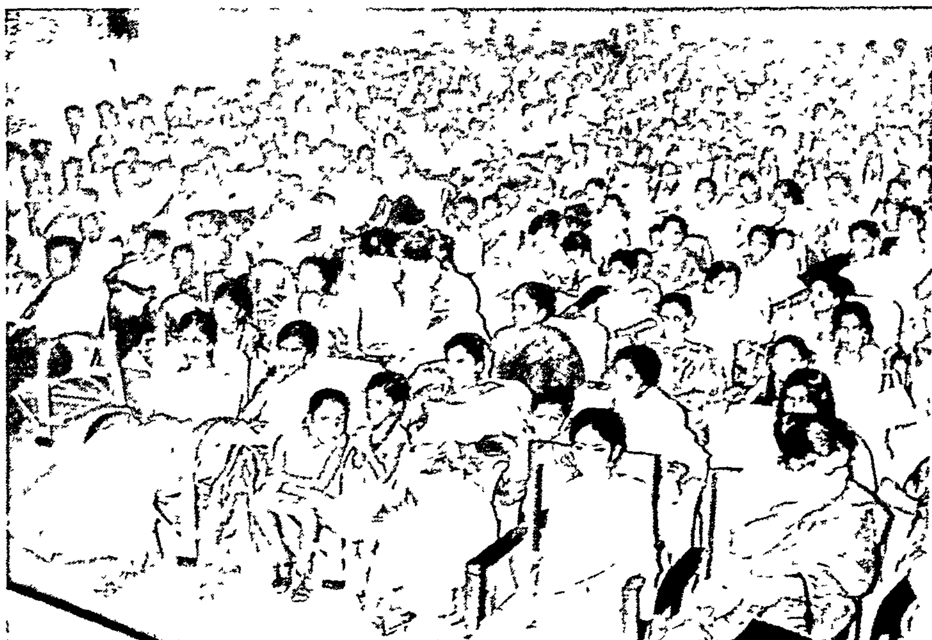
13.48 There were officers' and staff clubs on the Right Bank and in the Pylon and Hill Colonies, where games were played and cultural programmes were staged. One of the important departmental theatres was the Ranganatha Ranga Sala, named after the Chief Engineer. In this theatre were held important functions of the project such as sessions of the Institution of Engineers (India), felicitations, technical discussions, music, dances, dramas, social gatherings and religious discourses. This theatre is a permanent recreational centre even after the completion of the dam.

RESUME

13.49 Projects are situated in uninhabited areas across river gorges. Workers and staff are deprived of the amenities of life, specially in the early stage of investigations and construction. This is the reason for experienced staff and workers, refusing to join a project in the initial stages To attract skilled workmen and able officers, advance arrangements should be made for their essential amenities and facilities, such as, housing, water supply, medical aid, sanitation, roads, electrification of houses, and schooling for children. These arrangements, if delayed, would have an adverse effect on progress and will delay the schedules drawn up for the targets of a project. As the cost of these arrangements works out to only a fraction of the cost of the project, the planners should have a liberal and realistic outlook for providing timely and adequate facilities.



Hill Colony Girls' High School (St Joseph's) (*Para* 13 29)



A view of the festival gathering at recreation centre—(*Para* 13 46)

Children-participants of the Cultural Performance—(*Para* 13 46)
(Photographed with Author carrying Master Sridhar)



A view of the Cultural Fête with children's dance—(*Para* 13 46)

CHAPTER XIV

REHABILITATION

The construction of the Nagarjunasagar dam required the important and delicate humanitarian task of providing new life to the persons displaced as a result of the submergence of villages and hamlets in the reservoir formed. Therefore, the story of the construction of this project would be incomplete without discussing the problems which were solved in the task of rehabilitating the displaced.

The lake covering an area of 110 sq. miles (285 sq km.) displaced 4,824 families with a total population of about 24,400 in 44 villages These figures compare well with the Bhakra dam where, for a submergence area of 65 sq. miles (168 sq. km.), the population displaced was 30,000 covering 371 villages.

14.2 The number of villages that got submerged is very small when compared to the vast expanse of the reservoir. These villages were also scarcely populated. The area mostly consisted of forest lands and uncultivable tracts.

14.3 The task of acquisition of lands in the submerged areas and rehabilitation of the displaced persons was entrusted to a Special Collector, right from early stages of construction from 1956 He was given the requisite staff consisting of a Special Deputy Collector with supporting staff.

14.4 The submergence area of the reservoir lies in Miriyalaguda and Devarakonda taluks of Nalgonda district and Achampet taluk of Mahboobnagar district on the left bank and Palnad taluk of Guntur district on the right flank.

14.5 All the agricultural Patta lands in the submerged villages and village sites, including the houses and structures standing thereon, were acquired and compensation paid. The compensation for land was paid at the market value of the land on the date of the publication of notification and for houses as per the Public Works Department schedule of rates during the period.

14.6 Reserve forests were selected for establishing the rehabilitation centres. Twenty-four rehabilitation centres were established, nine in Guntur district on the right side of the Krishna and the rest in Nalgonda

district on the left. The centres were located on hill slopes and on the top of hills particularly to suit the life of tribal families like Lambadas and Chenchoos, who had herds of cattle and sheep.

Details of Rehabilitation

14.7 The entire rehabilitation programme was completed by 1969. Depending upon the holdings of land of various families, the compensation for lands was paid at the following scales per family in the rehabilitation centres :

	Free of Cost		At market value	
	Ha.	(Acre)	Ha.	(Acre)
(*a*) Families who have been living by cultivation for 3 years before July 1959 and who were having 2.07 ha. (5 acres) or less ..	2.07	(5.0)	..	..
(*b*) Displaced families 2.07 to 4.14 ha. (5 to 10 acres).	2 07	(5 0)	1.03	(2.50)
(*c*) Displaced families having 4.14 to 8.28 ha. (10 to 20 acres).	2.07	(5 0)	2 07	(5 0)
(*d*) Displaced families having more than 8.28 ha. (20 acres). ..	..	..	5.15	(12.50)

14.8 The area of forests de-reserved for rehabilitation to provide for house sites and for agricultural lands works out to 14,545 ha. in Palnad taluk of Guntur district and Miriyalaguda, Devarakonda, Bhongir and Huzurnagar taluks of Nalgonda district. Out of this area, an extent of 6,684 ha. of cultivable land was selected for assignment. The Chief Conservator of Forests of Andhra Pradesh who is the custodian of the land, handed over the above areas to the project authorities for allotment.

14.9 The following list gives the names of villages with the number of families affected and the number of people who were displaced.

Sl No.	Name of the village		Families affected	People displaced
1.	Kalasa H/O (hamlet of) Puttagudem	..	4	20
2.	Nandikonda	.	165	800
3.	Banjara Huts H/O Nandikonda ..	..	61	315
4	Gangarajupalli	..	123	615
5.	Gonemadka	..	65	323
6.	Edul Tanda	..	98	492
7	Rayavaram	..	22	100
8.	Bhagawan Tanda	..	119	605
9.	Yelleswaram	..	295	1480
10.	Pullareddigudem	..	149	740
11.	Krishnapur H/O Kandlakunta ..	..	9	48
12	Nidigal	.	270	1350
13.	Pottigutta tanda H/O Rayavaram .	..	66	330
14	Sunkisala	..	109	545
15.	Lambadigudam H/O Pullareddigudem	..	72	318
16.	Jammigadda tanda H/O Nidigal ..	..	113	558
17.	Suryaraopet	..	55	275
18.	Suryapet	..	61	299
19.	Bothulanta H/O Suryaraopet ..	..	275	1400
20	Guvvalagutta tanda H/O Nidigal ..		258	1058
21.	Chinnagummadam . ..	.	113	570
22	Monya Tanda H/O Chinnagummadam	..	105	582
23 24.	Madhavaram Madhavaram tanda }	..	290	1458
25.	Khannapur	..	72	363
26.	Chinnamungal H/O Paddamungal	..	253	1311
27	Haithul tanda H/O Chilkurthy .	.	13	68
28	Gonepenta H/O Ippalapalli	.	5	19
29.	Nakkalapenta H/O Azmapur ..	..	87	436
30	Nambapur . ..	..	88	449
31.	Peddagummandam . ..	.	183	1003
32	Suddabhavi tanda H/O Kasarajupalli		175	866
33	Peddamungal . . .	.	518	2791
34	Mulla tanda H/O Kanapur ..	..	9	38
35	Kottalagadda H/O Azamapur ..	..	47	215
36.	Kothapalli	..	31	113
37.	Bakkalingayappalli	..	46	235

Sl. No.	Name of the village Centres	Families affected	People displaced
38.	Yelmalamanda	149	748
39.	Keeryatanda H/O Suryaraopet	66	328
40.	Neddigadda tanda H/O Khanapur ..	10	49
41.	Madyatanda H/O Chinnagummadam ..	27	134
42.	Gajjalavenkayagudem H/O Chinnagummadam	5	27
43.	Babul tanda H/O Nidigal	114	581
44.	Kalia tanda H/O Sunkisala	29	149
	Total ..	4824	24204

14.10 A list of the rehabilitation centres opened in the various districts showing the number of families rehabilitated is shown below:

1.	Kothapullareddipuram	Guntur ..	269
2.	Kothanandikonda	Nalgonda ..	300
3.	Kalepalli	Nalgonda ..	65
4.	Tummercode	Guntur ..	86
5.	Latchammabhavi .. .	Guntur ..	258
6.	Muthakur	Guntur ..	280
7.	Dongapadu	Nalgonda ..	137
8.	Peddagettu	Nalgonda ..	157
9.	Dilwarpur	Nalgonda ..	64
10.	Yellapur	Nalgonda ..	67
11.	Teldevarapalli	Nalgonda ..	287
12.	Chitriyal	Nalgonda ..	313
13.	Chintapalli	Nalgonda ..	94
14.	Wazeerabad	Nalgonda ..	52
15.	Rajagettu	Nalgonda ..	96
16.	Gurrambodu	Nalgonda ..	235
17.	Pogilla	Nalgonda ..	174
18.	Yelmalmanda	Nalgonda ..	271
19.	Kambalapalli	Nalgonda ..	409
20.	Mulkalapalli Venkatapur ..	Nalgonda ..	42
21.	Pasuvemula No. I	Guntur ..	170
22.	do. No. II	Guntur ..	329
23.	do. No. III	Guntur ..	218
24.	do. No. IV	Guntur ..	273
			4646

Organisation

14 11 The entire land acquisition and rehabilitation operations were under the charge of a senior officer taken from the Revenue Department, of Collector's rank and he was designated as Special Collector. The same person was also in charge of land acquisition, localisation and other works of the Jawahar and Lal Bahadur Canals For the land acquisition and rehabilitation, under the control of the Special Collector, a Special Deputy Collector worked with adequate supporting staff drawn from the Revenue Settlement Surveys and Forest Departments

14 12 The surveys connected with land acquisition were under the control of an Executive Engineer who had also undertaken the civil works of rehabilitation centres for provision of roads, wells, schools, temples, chavdies etc.

The Executive Engineer was under the control of the Superintending Engineer, who was in charge of the buildings and roads for the construction of the Nagarjunasagar dam

14 13 The surveys connected with the acquisition of land in the submergence area were under the charge of an Assistant Engineer, who was assisted by three supervisors and these were assisted by five maistries, twelve laskars, six drummers and thirty coolies for jungle clearance. These arrangements were necessary as the areas to be surveyed were dense forests infested with wild animals and, therefore, the staff had to be adequately protected

The construction of civil works for the rehabilitation centres was entrusted to a separate Assistant Engineer under the Executive Engineer for rehabilitation

Demarcation of areas for Compensation

14 14 Work in respect of the demarcation of the full reservoir level of 590 ft. (182.9 m.) was started in March, 1961. The area under submergence in the reservoir at the maximum water level of 594 ft. (184 1 m.) was started in March, 1961. The area under submergence in the reservoir at the maximum water level of 594 ft. (184 1 m) was surveyed The level of 594 ft. (184.1 m) was taken into consideration while working out the submergence programme. Along the mountains to demarcate the base contour 600 ft level (186 m), rubble heaps were built at frequent intervals as cairons duly whitewashed to facilitate visibility from distance.

14.15 On a reconsideration, it was thought that the maximum reservoir level of 594 ft. (184.1 m.) would only reach with a flood discharge

of 1,500,000 cusecs (42,450 cumecs), which would only occur very rarely. Therefore, land acquisition was restricted to only full reservoir level of 590 ft. (182.9 m.) as compensation payable to lands.

14.16 The proposals for land acquisition were made during different years with the rise of water level in the reservoir. The acquisitions were taken up in different years at various levels as follows :

Level in ft.	Level in metres	year
360	111.60	1962
420	130.20	1963
470	145.70	1964
550	170.50	1965
590	182.90	1966

14.17 During the survey operations, land plans and schedules with necessary certificates were prepared and sent by the Assistant Engineer to the Special Collector. Check levels were carried out, bench marks established and village Patta lands demarcated.

14.18 The demarcation was not done in places where lines ran wholly in forest lands specially in gorges of the river, and where arduous and risky work was involved in surveying steep slopes, since no compensation was involved in the case of such lands which belonged to the Forest Department and not to private Pattadars (bonafide owners).

Detailed plans of submersible areas were made to a scale of 4″=1 mile (1 : 15840) from aerial survey maps and contours of elevation 450, 510, 570 and 590 feet (139.5, 158.10, 176.7 and 182.9 metres) were marked on the survey plans.

14.19 In addition to the villages, the permanent objects were also marked on the plans. Regular plans and estimates were prepared for the acquisition of buildings and non-residential buildings in all submersible areas of villages The villagers of these areas were evacuated to rehabilitation centres in a planned way as the water level in the reservoir rose with the construction of the dam.

14 20 More new tracks were laid by the Department for shifting the villages from the submersible areas. The work of dismantling and transfer of temples was done by the survey party. Important idols were shifted after observing religious formalities.

Archaeological and Sacred Shrines under Submergence

14.21 The historic temples of Yelleswara Swami (Shiva) and Madhavaswamy (Vishnu) near Yelleswaram village came within the reservoir submergence area. They were dismantled and important architectural pieces, including the main idols were re-established in Vijayapuri North.

14.22 At a distance of seven miles (11.3 km.) above the dam site lies the famous valley of Nagarjunakonda, the abode of the great Buddhist scholar and saint, Acharya Nagarjuna, of the second century A.D. This valley, at the time of excavation, revealed treasures of historic and pre-historic monuments. Detailed accounts of the archaeological excavations, the monuments and their transportation are given in Chapter II.

14.23 The temples of Yelleswara Swami and Madhavaswamy were ordered to be built by the Government on the left bank of the Krishna. The Endowments Department of the Government of Andhra Pradesh was assigned to build these temples with the old monuments which were shifted to the site from Yelleswaram. Though the Government had sanctioned Rs. 80,000, the work could not be started on account of delays at various levels.

14.24 For the temples which existed in the villages which went under submergence, the Government had sanctioned Rs. 7,500 for each temple and 19 temples were constructed in various rehabilitation centres at the cost of the Project.

Facilities to Displaced Persons

14.25 As a generous gesture to the landless poor, even encroachers on Government lands, who were in continuous possession for three years, were given compensation at the rate of one-third of the market value of the land.

14.26 In addition to the payment of compensation to their land at the rates prevailing on July 1, 1953, as required under the Nagarjunasagar Project Acquisition of Lands Act XXXII of 1956, the following concessions and facilities were given to the displaced families:

(i) Displaced families who were living by cultivation for the last three years and whose holdings in the submersible area and elsewhere did not exceed 20 acres (8.1 ha.) were granted, free of cost, dry land not exceeding five acres (2 ha.) subject to the condition that the grant should be just enough to make his total possession, elsewhere and in the new rehabilitation centres aggregates to 10 acres (4.0 ha.) dry.

(ii) Displaced families owning five to ten acres (2 to 4 ha.) were granted 2½ acres (1 ha.) and displaced families owning ten to fifteen acres (4 to 6 ha) were granted five acres (2 ha).

(iii) Those owning lands up to 20 acres (8.1 ha.) were granted 12½ acres (5 ha). The payment of compensation at the market value in respect of the above was subject to the condition that the total land for which families would become eligible did not exceed 20 acres (8.1 ha) in the submersible area or elsewhere.

(iv) Each displaced family was given a house site free of cost up to 10 cents (.04 ha.). Assignment over this limit was made on payment of cost subject to a maximum of 25 cents (0.10 ha.), including the free grant of 10 cents (.04 ha.).

(v) Each displaced family of cultivators who was Pattadar of less than 10 acres (4 ha.) was granted Rs. 100 as loan and another Rs. 100 was granted to meet the expenditure on reclamation and levelling of lands being assigned to them in the rehabilitation centre site by the project.

(vi) The displaced families received a compensation of Rs 500 or less for their house property in the submersible village. An ex-gratia sum was paid subject to a maximum of Rs. 300.

(vii) They were provided free transport to enable them to shift along with their belongings from the submersible village to the rehabilitation centres.

(viii) They were permitted to remove free of cost dismantled materials of their residential buildings and, in the case of non-residential buildings, removal of dismantled materials was permitted on payment of 75 per cent of the assessed cost.

(ix) Wells were provided in the new rehabilitation centres at the rate of one well for fifty families

(x) Access roads and common facilities such as schools, temples etc. dislocated by the project in the submersible villages were provided with new centres at the cost of the project.

(xi) Land owners could use the lands acquired in the submersible villages until such time as flooding occurred. These were given on lease or rent which depended on the assessment payable for the lands.

(xii) Chavdies (community centres) and other facilities were also provided at the cost of the project for the common use of the displaced families in the rehabilitation centres.

14.27 Additional extents of land, if required by the displaced persons, were given for house sites on payment of cost, subject to a maximum of



Drinking Water Well at Rehabilitation Centre—(*Para* 14 30)

25 cents (0.10 ha) But such demands were entertained only from deserving cases on consideration of status and needs of the families and the extent of house site owned by them in the submerged village.

14.28 In addition to the compensation paid for the above in the submerged area, an ex-gratia amount was also granted to construct a modest house in the rehabilitation centre. Families which got compensation of less than Rs. 500 were given the difference of amount to make up the total sum of Rs 750. But this difference was paid subject to a maximum ceiling of Rs. 300. Towards this ex-gratia, 2955 families were eligible for an amount of Rs. 87,674 which was paid

14 29 In respect of land owners, only people having 20 acres (8.1 ha.) or less under the submersible area or elsewhere were eligible for a free grant of dry land of five acres (2 ha) to make his total possession in the new centre, including what he possessed already elsewhere, not exceeding 10 acres (4 ha.). The assignee was not entitled to alienate in any manner the land given free to him for a period of five years from the date of assignment. People cultivating Government Poramboke lands in the submerged areas were also eligible for the free grant of five acres (2 ha) The Government also ordered assignment of land at the rate of 2½ acers (1 ha.), and five acres (2 ha) for persons owning 5 to 10 acres (2 to 4 ha.). If more than 20 acres (8.1 ha) was possessed by any person, he was given 7½ acres or 3 ha. The assignees of the land at market value were permitted to pay the market values of the land in five instalments, irrespective of the amount to be paid.

14.30 In every rehabilitation village, one drinking water well was provided free of cost. In 24 rehabilitation centres, 77 drinking water wells were sunk The sites were selected with the help of a geologist and the expenditure was met from the project funds.

14 31 School buildings were also constructed in 24 rehabilitation centres and a chavdi (community centre) was constructed at a ceiling price of Rs. 10,000 in each of the rehabilitation centres. The design of temples, schools or chavdies was made on a modest scale and 20 chavdies were constructed in different rehabilitation centres.

Loan Facility

14 32 Displaced families who were Pattadars and possessed less than 10 acres (4 ha.) were granted an amount of Rs. 100 each to meet the expenditure of levelling lands etc They were granted loans after taking security bonds This amount was not channelled either through the land mortgage bank or co-operative societies. The loan was recoverable in five annual instalments An amount of Rs 120,000 was paid towards loans for 1200 families.

14.33 For displaced families of cultivators having less than 10 acres (4 ha.), Rs. 100 was given to each family to meet the expenditure of reclamation and levelling of the land assigned to it. An amount of Rs. 121,200 was paid as loans for 1212 families.

Cost of Rehabilitation

14.34 The Land Acquisition Act I of 1894 as amended by Act No XXXII of 1956 (Nagarjunasagar Project Land Acquisition Act) was made applicable to the area submerged by the reservoir. The values of land were frozen at the level prevailing on July, 1, 1953. The cost of land acquisition (rehabilitation of the submergence area) and establishment was Rs 10 3 million and Rs. one million respectively

14.35 Forest areas were transferred free of cost first to the project and subsequently to the Revenue Department, subject, however, to any revenue realised from the assignment of land at market value being credited to the Forest Department.

14 36 For surveying and demarcating the full reservoir contours of the Nagarjunasagar reservoir, an estimate for Rs. 38,000 was sanctioned. The estimate provided for the pay of maistries, lascars, the cost of demarcation stones, village plans and labour for clearing jungles wherever necessary to facilitate survey work.

14.37 Where free transport could not be provided, a lump sum amount in cash was given to each family in lieu of free transport at a uniform rate of Rs. 1.75 per mile (Rs. 1.1 per km.).

14.38 Out of the 4824 displaced families, 1971 were transported in lorries provided by the Government. The others who moved on their own accord were paid Rs. 178,729 towards transport charges. For agricultural land submerged by the reservoir, Rs. 7.173 million was paid as compensation in addition to Rs. 3.06 million paid for houses and structures

14.39 Towards provision of roads, wells, schools, temples and Chavdies for the civil works, an ex-gratia payment for transport charges etc. amounting to Rs. 0.96 million was made. Twenty rehabilitation centres were established, 3282 families settled and 7844 acres (3175 ha.) surveyed and demarcated into plots at the centres.

14.40. To facilitate proper maintenance of several items of civil works in the rehabilitation centres, they were taken over by the Revenue Department. The temples were handed over to the Endowments Department and the internal roads, approach roads, school buildings and wells were taken over by the respective Panchayat Samithies.

RESUME

14 41 The Displacement of large numbers of people from their villages was a colossal, and a human problem It required tact, prompt action for payment of compensation and timely arrangements in the rehabilitation centres The displacement of people was inevitable consequent upon the formation of the lake. Advance action on the part of the engineers with the co-operation of the displaced people made the rehabilitation process smooth and prompt. Generous assistance was given to the displaced people for starting a new life, better than the one they had lived earlier. Land for land, and facilities of water, road, communications and other additional benefits like schools and places of worship were given to the new centres. The new villages have been properly laid out from the point of view of health and sanitation The people, mostly Lambadas, a tribal community, were living for ages in the hutments which went under water The evacuation programme had to be accomplished without using forceful methods and avoiding loss of life and damage to properties well before the rise of water in the lake Due to persistent efforts by the officers concerned and by affording better facilities at the new rehabilitation centres, it was possible to win over the displaced persons. The work of rehabilitation started early in 1958 and was completed by 1967 The process of evacuation was peaceful without any untoward incident. The displaced persons were given a psychological feeling that they were given facilities to start a new and vigorous life with the satisfaction that they had also contributed in their own way to the materialisation of the mighty Nagarjunasagar project.

14.42 The displaced persons, numbering 24,204 were rehabilitated in 24 centres in two districts and four taluks The dispersal of the population and giving them amenities was rather costly. It would have been economical if all of them were to be housed in fewer centres. Building modern villages with infrastructure to facilitate agriculture and cottage industries, even if it meant higher cost, would have given a better life to the displaced A proper policy for rehabilitation requires a study in depth in future projects.

CHAPTER XV

DEVELOPMENT OF IRRIGATION

Agriculture is the main source of employment in India for nearly 75 per cent of the population. In India, utilisation of water for irrigation was a subject of specialisation even in ancient times. During the reign of Chandragupta Maurya in the third century B.C. stress was laid upon the utilisation and control of water. This fact was recorded by the famous Greek Ambassador, Megasthenes, who visited India during the reign of Chandragupta Maurya.

As far back as 1902, the Irrigation Commission had pronounced that the Krishna basin had bigger tracts subject to frequent scarcity and famine than any other river basin in India. In spite of this, the Krishna remained un-harnessed till 1956, when the construction of the Nagarjunasagar dam was started. Nagarjunasagar has a huge canal system which supplies water to a million hectares of irrigated crops.

15.2 The area of the Nagarjunasagar project is one of the less developed and prosperous parts in Andhra Pradesh. The principal source of livelihood for the people of these areas is agriculture which languished on account of lack of irrigation facilities, uncertain and inadequate rainfall, lack of incentives, and the inability of farmers to adopt modern techniques of agriculture. One of the outstanding benefits of Nagarjunasagar project is particularly in the cultivation of rice. This project helps eliminate food imports considerably, particularly rice.

Early Development

15.3 The success of a project depends on its fulfilment, execution of works and realisation of the benefits. The development of utilities for which a project is designed is still more important because, on it depends the success of the plan. It must be realised that, after the works are completed, a huge capital is locked up piling up interest charges every year until the revenues realised compensate the interest charges. Sound financial principles demand the treatment of interest charges every year as part of the capital until the revenues realised compensate for them. For a project requiring 10 years for completion and another 15 years for the net revenue to balance interest charges, the accumulated arrears of interest amount to as much as 60 per cent of the capital outlay, thereby increasing the capital cost. Therefore, every attempt should be made to

supersede interest charges as early as possible, by the full utilisation and prompt development of the project.

15 4 Development activities should therefore precede the construction of the project, so that when the resources of the project are made available, there will be no delay in their utilisation. The development of irrigation requires the investment of quite a large capital, agricultural implements, cattle power and adequate labour, besides seeds and manures. The resources of underdeveloped tracts are limited and the requirements should be determined well in advance Water supply, education, roads, new villages and towns, marketing centres, agricultural farms and cattle breeding farms etc , improvement of public health and medical aid are among the essential infrastructure required for the development of any project.

Management by Engineers

15.5 In addition, proper management is essential for the delivery of water at such times and in such quantities as will enable the best crops to be raised. Therefore, the utilisation of irrigated water supplies being of a technical nature, a team should be set up to tackle this complex problem, consisting of experts in engineering, agriculture, soil chemistry, medicine, public health etc. Among these experts, the engineers have an important role to play as it is their plan that has to be carefully executed for the fulfilment of the desired benefits

15 6 Systematic development for the rapid utilisation of the irrigation potential took place only recently in India. This requires a co-ordinated attempt, since the command area should be fixed well in advance. Extensive investigations have to be conducted of the soils and crops which are suited to local soils depending upon the climatic conditions. Irrigable lands have to be properly levelled and kept ready to receive and retain water. Extensive planning is also necessary for the supply of agricultural implements, improved seeds, fertilisers, approach roads, markets, storage arrangements for grains and other infrastucture.

Development of the Canal System

15.7 To understand the development under the project, a brief description of the canal system is given below :—

The Nagarjunasagar canal system is one of the largest of the irrigation projects in India Two huge contour canals take off from the main reservoir, one from each flank. The right main canal is one of the largest irrigation canals in the world, running upto 202 km. serving the districts of Kurnool and Guntur. It is named after India's first Prime Minister, Mr. Jawaharlal Nehru and is called the 'Jawahar

Canal '. The left canal runs upto 185 km. serving the districts of Nalgonda, Khammam, Krishna and West Godavari and is named after the second Prime Minister of India, Mr. Lal Bahadur Shastri. It is called the ' Lal Bahadur Canal '.

Jawahar Canal

15.8 The right main canal takes off through a head regulator from the non-overflow section of the Nagarjunasagar dam on the right flank. The canal with a head discharge capacity of 594.3 cumecs flows through a deep open cut for a distance of 1.6 km. and enters the Pasuvemula tunnel 8.23 metres in diameter and 1260 m long For the ultimate discharge of 594.3 cumecs, twin tunnels have been proposed ; only one of these has been built to carry the first stage discharge of 311.5 cumecs (11,000 cft./sec.). The second tunnel will be bored with the development of the ayacut in the second stage. After passing through the tunnel and flume section, the canal attains its normal section of 76.2 metres in width and 4.57 metres in depth. After emerging out of the tunnels, the canal crosses a number of streams, of which the Buggavagu is crossed at km 28 by a level crossing forming the Buggavagu reservoir. After crossing the Buggavagu reservoir, the canal crosses the Naguleru at km. 55 by an aqueduct Thereafter the canal takes a reverse turn at km 83 at Nekarikallu and covers a number of deep cuts varying in depth from 14 m. to 36 m. In the region from km. 135 to km. 176, it crosses five major streams of Peddakhandaleru, Chinnakhandaleru, Duvvuleru, Teegaleru and Gundlakamma through aqueducts. The canal, designed as a contour canal, carries 311 6 cumecs upto km. 202 and covers an ayacut of 0.47 million hectares, upto the Musi river. After the Tribunal's award on interstate sharing of Krishna waters, the second phase proposal has been dropped.

The distribution system consists of a total length of 33,000 km of branches and distributaries. to irrigate 0.475 million hectares, besides stabilising 48,000 hectares of second crop in the Krishna delta.

Lal Bahadur Canal

15.9 The left main canal takes off from the foreshore of the Nagarjunasagar reservoir through an approach cut from an independent head regulator to discharge 311.5 cumecs, without lining and 426 cumecs after lining The canal will irrigate 0 397 million hectares in Khammam, Krishna and West Godavari Districts

15.10 From the take-off point, the canal passes through a deep cut and enters a horse-shoe shaped tunnel of 9 7 m dia. and 2286 m. length. The first 11 km. of the canal passes through a number of ridges. The canal crosses Halia river by means of a massive masonry aqueduct

at km. 19 and negotiates the Devulapalli stream by a level crossing at km. 43. In km 72 the canal crosses the Chinnapalair river by means of a buttress type aqueduct. In km 74 it crosses the Musi river by means of an arched type aqueduct The canal crosses the National High Way between Hyderabad and Vijayawada at km. 136 by a level crossing and then crosses the Munneru by means of an aqueduct just down stream of the confluence of the Akheru and the Munneru rivers near Khammam at km. 177. At km 185, the tail end branch takes off and runs for a length of 125 km upto Thammileru valley

15 11 In the right canal, the water available is not adequate to irrigate all the commandable lands Therefore, it was proposed to irrigate only an area of about 0.5 million hectares with a lighter cropping pattern of 1/3 wet and 2/3 as irrigated dry to distribute the benefits of the project to as large an area as possible. The proportion of ayacut to the actual cultivatable commanded area varies from 100 to 66 per cent after deducting the beds of the village tanks, roads and anti-malarial zones, a kilometre round each village and Poramboke (unutilisable) lands

In the Lal Bahadur Canal, the proportion of wet and dry irrigation is in the ratio of 2 : 1 In view of the limited area available for irrigation, the cropping pattern is all wet up to km 136 up to the Palair reservoir to the extent of 1,30,000 hectares Beyond this point, the proportion of wet and dry lands would be in the ratio of 2 : 1 as given above.

BRANCH CANALS AND DISTRIBUTARIES

15.12 All off-takes from the main canal with head discharges of 500 cusecs (14 15 cumecs) and above are included in this category There are seven branch canals in the right canal Out of these, the Guntur and Ongole branch canals are the biggest in the system with discharges over 2,500 cusecs (70 73 cumecs)

In the left canal, there are six branch canals. The biggest are the Muktyala, Nandigama and Kondapalli and Bonakal Branch canals with discharges over 2000 cusecs (56.6 cumecs)

All off-takes from the main or the branch canal are termed major distributaries and the irrigated area served by each is bounded by valleys

All off-takes taking off from a major distributary are termed minor distributaries and serve irrigated area bounded by minor valleys.

All pipe off-takes serving less than 40.5 hectares (100 acres) of irrigated area are called field channels

In the general design of the canals, Manning's formula was adopted with the co-efficient of rugosity taken as 0 018 for the lined sections and 0 0225 for the unlined sections Velocities up to 1 15 metres per second were allowed in the unlined canals, 1.7 metres per second in the lined

canals, 2.6 metres per second in the flumes and 3.3 metres per second in the aqueduct troughs. (See Irrigation Map).

The distributory system is designed in the unlined section for discharges less than fifteen cumecs. After a careful study of the various sections and the criteria for non-silting, the optimum depth of supply was determined by the conventional formula :

$d = \left[\frac{q}{3} \right]^{\frac{1}{3}}$ where d is the depth in ft., and q is the discharge in cusecs at full supply. The sections were designed adopting co-efficient(n) of rugosity .0225 for discharges exceeding 3 cumecs., .025 for discharges exceeding 0.3 cumecs, and .0275 for smaller channels, adopting the formula for velocity $v = d^{\frac{1}{2}} = \frac{1.4858}{n} r^{2/3} s^{1/2}$, where r = hydraulic mean depth in feet, and s = bed gradient.

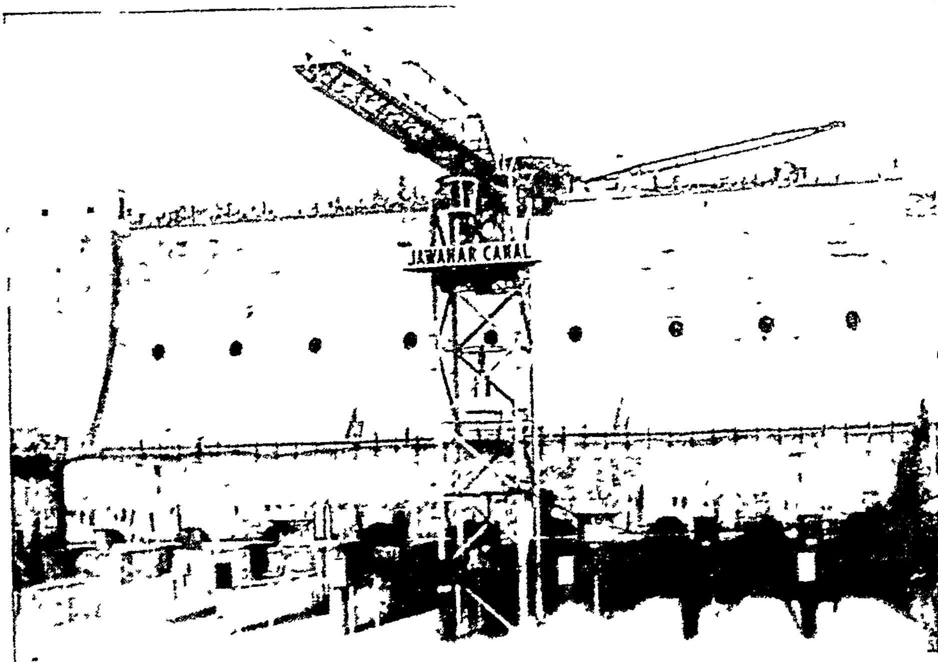
Organization for Development

15.13 For the development of the ayacut, a Member of the Board of Revenue of the Government of Andhra Pradesh was appointed as a Commissioner to co-ordinate activities of several departments. Under his chairmanship, the Government also constituted a State-level committee for development of the Nagarjunasagar ayacut, to facilitate the allocation of specific tasks to the departments concerned, its development and to secure their co-operation in implementing the agreed programmes The committee consisted of the Secretaries to Government and Heads of Departments concerned, the chairman of the Zilla Parishads of the districts concerned and the President of the Andhra Pradesh Co-operative Central Land Mortgage Bank. Land acquisition and development were assigned to a Special-collector with supporting staff including several Deputy Collectors. In addition to this, a Joint Director of Agriculture, an Agricultural Engineer, a Joint Registrar of Co-operative Societies with their supporting staff were also appointed for ayacut development and for implementation of the various development activities.

15.14 In the Nagarjunasagar project, arrangements were made for co-ordination at the field level to accelerate the development of the ayacut. The State Government constituted several four-member teams, each consisting of representatives of the Revenue, Agriculture, Irrigation and Co-operative Departments, with a Block Development Officer as the convener. These teams toured the villages to advise the farmers. A team of four officers from the following departments visited the villages to solve the problems faced by the cultivators :

(i) One P.W.D. (Public Works Department) Supervisor for regulating the supply of water

(ii) One Revenue Inspector for settlement of land and water disputes



Jawahar Canal Head Regulator—(*Para* 15 3)

Chandrawanka aqueduct in Mile 12 of Jawahar Canal—(*Para* 15.8)

1967 when the diversion tunnel gates did not close, he was supervising the works connected with restoration operations. Due to failure of a cross wall, water rushed into the pit where he was working and got washed away through the tunnel along with his assistants named below :

(i) Mr Ratnaker Rao, a Graduate Engineer, 22 years, joined department as a Junior Engineer and served for two years and was a sincere and hard working youth of promise. He was a bachelor and left a widowed mother.

(ii) Mr Basvaiah, Supervisor. He was a diploma holder, very dutiful and well-behaved.

(iii) Mr P V. Krishna Murthy. As a Section Officer he was working with M/s. Escorts Ltd. and was deputed to the department for erection of the gates.

(iv) Mr. Ahmed Kutti He was a skilled worker in the gate erection.

(v) Mr.Shankara Narayana. He was working as a maistry in mechanical division.

The dependents of the above persons were compensated.

Mr. Veerabhadra Rao, Supervisor

17.6 After taking his diploma in Civil Engineering from Kakinada College, Mr. Veerabhadra Rao, joined Nagarjunasagar as a Supervisor in 1960 and served up to 1962. When he was travelling in a lorry to Madras for the procurement of gas cylinders he met with an accident at Gummadipundi near Madras and died on the spot. He was a bachelor and left his widowed mother helpless. As per rules he was not entitled for compensation. But the staff raised donations amounting to Rs. 5,000 and purchased landed property for his dependent mother

Mr. Maqdoom, Supervisor

17.7 Mr. Maqdoom joined as a Supervisor in 1965. He was working round the clock with disregard to his health. He met his unfortunate and premature death in 1969 due to heart attack at the site and left his widowed mother as a dependent. The staff donated Rs. 5,000 and purchased a small house for her at Hyderabad for a living.

Similar subscriptions were raised by the staff and contractors for the dependents of all the accidentees who could not get government compensation in the project under the rules. There was no martyr whose dependents were left helpless.

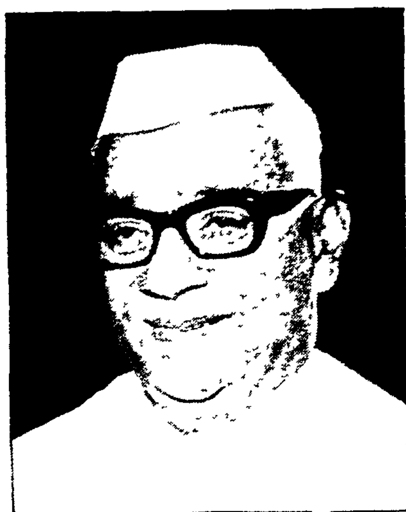
CHIEF MINISTERS



Dr N Sanjiva Reddy—(*Para* 17 16)



Mr D Sanjeevayya—(*Para* 17.16)



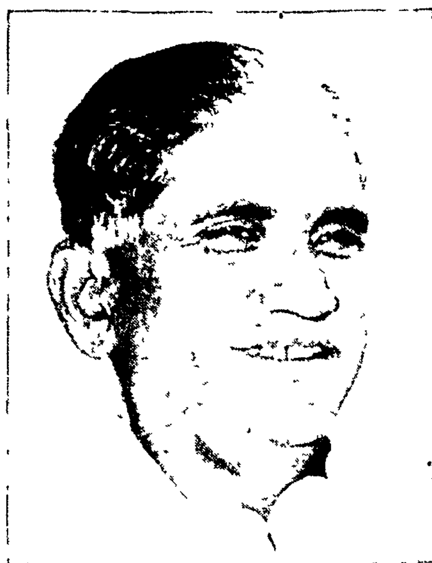
Mr K Brahmananda Reddy (*Para* 17 16)



Mr P V. Narasimha Rao—(*Para* 17.16)



Mr. J. Vengal Rao (*Para* 17 16)



Dr. M Channa Reddy (*Para* 17.16)

MINISTERS



Mr. A. C Subba Reddv—(*Para* 17 16)



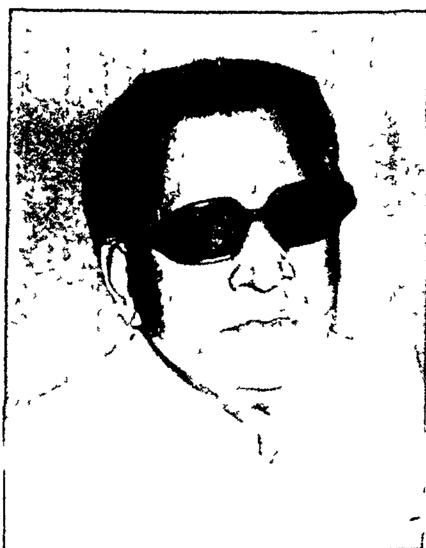
Mr J V. Narsing Rao—(*Para* 17 16)



Mr Seelam Siddha Reddy—(*Para* 17.16)



Mr P Narsa Reddy—(*Para* 17.16)



Mr G. V. Sudhakar Rao—(*Para* 17.16)

Boat Accident

17.8 Before construction of the bridge across the river on the down stream side of the dam, boats were plying at a ferry side, down below the dam site. Unmindful of the rise of water in the river, a motor launch was returning on 17th of October 1956 from the right to the left flank carrying eight passengers. The engine of the launch failed and the launch drifted with the current The operator and six persons were drowned. Mr. V. B. Naidu, Sub-Inspector of Police who was travelling, escaped as he was washed away to the shore He narrated the causes of drifting, consequent to failure of the petrol-driven engine which had no stand-by. The driver could have escaped by jumping into the river But he tried to repair the engine to the last minute before he was himself drowned Before the sinking of the boat some persons jumped into the river for swimming to the shore but could not face the current.

Bridge Accident

17.9 On 30-9-1964, there was an unusual and unprecedented flood of over a million cusecs in the Krishna river Consequently, some spans of the construction bridge on the down-stream side of the dam collapsed. At that time, a retired and devoted Supervisor of the Electrical Division, Mr. Radhakrishna Naidu, hailing from Hyderabad, while he was trying to rectify the telephone line, was carried away along with his helper due to the collapse of the span on which they were working

Scaffolding Accident

17.10 A 250 feet high scaffolding was under construction on the down-stream of block 43. The scaffolding was nearly completed with approach connections to the top of the dam The bracings and anchors of the high scaffolding had yet to be finished, which were very important for the stability of the scaffolding. The Carpenter in-charge blocked the scaffolding against public use. In spite of this, the workers who had to start the work when the scaffolding would be ready, wanted to perform Puja (Prayers) a couple of days earlier, on 16-1-1967, which was an auspicious day. They dismantled the barricades and overpowered the carpenter who stopped them from going While the persons were reaching the top, the entire structure came down and ten persons, whose names are given below, were killed :

1. R Chinniah
2. D. Yohan
3. G. Ananda Rao
4. J. Ramulu
5. A. Malla Reddy

6. V. Mariyamma
7. Abdul Aziz
8. Bala Krishna
9. Rama Rao
10. B. Lingappa

These names have appeared in para 17.4.

Outbreak of Epidemic

17.11 During the year 1957, cholera broke out in an epidemic form in the labour colony situated on the left bank of the river. In spite of having protected water supply through taps, the labour drank the river water which was infected. There were five fatal casualties. The epidemic was, however, effectively controlled by mass innoculations and it did not recur during the rest of the period of construction.

Road Accidents

17.12 Several accidents on rubble lorries occurred due to labour travelling in the lorries for loading and unloading operations. These accidents could have been prevented by prohibiting labour travelling in the lorries loaded with rubble In later periods of the construction, the labour was restricted from travelling in loaded lorries and this helped in reducing such accidents.

Miscellaneous Accidents

17.13 Due to electrocution, on the right bank, on 18.4.1965, two workers Messrs Anam Pitchi Reddy and Katti Venkaiah were killed on the spot. The insulation of a wire, which was feeding light points in a G.I sheet roofed shed, was cut by the sharp edges of a sheet, which was vibrating due to winds Thus, the sheets came in contact with the live wire and got energised and killed the workers who touched them.

17.14 Mr. Kunjee Mohammad was a Foreman, and expert in blasting and a sincere worker. He died in a road accident, while he was crossing the road opposite to the Central Office. He was run over by a lorry and died on the spot. He hailed from Kerala State.

Mr. Mohammed, a skilled worker from Kerala State, was crushed at the Washington crane while he was directing rubble lifting operations on the crane track.

Dr. K. L. Rao

17.15 The Architect of this historic monument is Dr. K. L. Rao But for his outstanding expertise, genius, keen interest, strenuous

efforts, it would not have been possible to build efficiently in the shortest time Nagarjunasagar Dam, the largest masonry-structure of the world. His able guidance and masterly advice were available throughout, right from the investigations up to the completion. It was he who selected the final site in 1955, and studied all the intricate problems encountered at various stages. He served the project in various capacities, in the Central Water and Power Commission, Government of India, as the Member of Designs and Research and later as a Member of Parliament and ultimately as the Union Minister for Irrigation and Power. With his selfless and dedicated work and tenacious efforts, he was responsible not only for building Nagarjunasagar project but also for building various other irrigation and power projects in the country. His eminent services in building irrigation and power projects in India, will be remembered for all times to come.

Ministers

17.16 When the Joint Report on Nagarjunasagar Project was prepared in the year 1954, Mr. Burgula Ramakrishna Rao was the Chief Minister of erstwhile Hyderabad State and Mr. Tanguturi Prakasam was the Chief Minister of the Andhra These two Chief Ministers were responsible for resolving many problems in the joint venture. Mr B Gopala Reddy, who succeeded Mr. T. Prakasam as Chief Minister of Andhra State also contributed very considerably in following up the scheme envisaged in the joint report After the formation of Andhra Pradesh State, on November 1, 1956, the following Chief Ministers played eminent roles for the materialisation of the gigantic project :

Dr. N. Sanjeeva Reddy
Mr. D. Sanjeevayya.
Mr. K. Brahmananda Reddy.
Mr. P. V. Narasimha Rao.
Mr. J. Vengal Rao.
Dr. M. Channa Reddy.

The following were the Ministers in-charge of Public Works (Irrigation Department), who had taken keen interest in giving fillip to the project works .

Mr. A C. Subba Reddy.
Mr. J. V. Narsing Rao.
Mr. Seelam Siddha Reddy.
Mr. P Narsa Reddy
Mr. G. V. Sudhakar Rao.

staff and he ably organised the construction activities from 1957-1962, when he retired after his outstanding record of work.

Mr. M. A. Rahman

17.24 Born in 1918, he took his engineering degree from the University of Madras. He was the first Superintending Engineer of the Right Canal (Jawahar Canal). He was the founder of the Nagarjuna sagar Sub-Centre, of the Institution of Engineers, India. He organised a Labour Co-operative Society on the Right Bank of Nagarjunasagar for the dam and canal workers. The difficult Pasuvemula tunnel, Buggavagu dam and other important structures of the Jawahar Canal were well planned and built during his time. In 1961, he became the Chief Engineer, Srisailam Project He served as a Member, Central Water and Power Commission from 1967 to 1969. In the year 1969, he was selected as a Project Manager of United Nations Development Programmes, in Afghanistan.

Mr P. T. Malla Reddy

17 25 Born in 1914, he took his M.I.C.E. (London). He was the first technical Secretary of the Nagarjunasagar Control Board. Thereafter, he joined as Superintending Engineer, Nagarjunasagar Dam, in 1956 During his tenure from 1956 to 1958, greatest progress was achieved in the construction of roads and buildings of the Project. Later, he became Chief Engineer (General) P.W D. in 1962. In 1969 he was selected as the Chairman of National Projects Construction Corporation and retired in 1970 after a glorious record of service.

Mr. K V. Sreenivasa Rao

17.26 He took his engineering degree from the Osmania University. He was a brilliant scholar of his days and joined the P.W.D. as Assistant Engineer in the year 1939. He joined the Nagarjunasagar Dam in 1956 as the first Superintending Engineer of Inspection and Control. He laid down procedures to ensure effective inspection and quality control of works He served in the project till 1958 and was transferred to the regular P W.D. He became Chief Engineer in 1962 and later he was promoted as a Member, Central Water and Power Commission, Government of India and served there for two years. In 1972 he was appointed as the Chairman, Andhra Pradesh State Electricity Board and retired in 1974 with an outstanding record of service.

Major M. Rangaswamy

17.27 He took his engineering degree from the Osmania Engineering College. After serving the army, he joined the P.W.D. as Executive

Engineer. He served from 1958 as Superintending Engineer in-charge of Lal Bahadur Canal for two years and then joined Nagarjunasagar Dam Organisation as the Superintending Engineer for Inspection and Quality Control In addition to his normal duties, he took keen interest in improving the labour amenities and solving their problems. In the year 1963, he became the Chief Engineer of Bharat Heavy Electricals Limited Hyderabad, and retired in 1967 after a meritorious service.

Mr. K. Ramabrahmam

17 28 Born in 1912, Mr. K. Ramabrahmam graduated in Engineering from the University of Madras. He had a good record of work in the State Electricity Department where he held charge of construction of various important projects, viz, Jalaput Dam in Machkund Hydro electric Scheme, Pykara, Thambraparni and Sileru. He joined Nagarjunasagar Dam in 1963 and served up to 1967. He ably managed the Inspection and Control Organisation in addition to building earth dams and diversion tunnel. He retired in 1967.

Mr. T. C. Krishna Rao

17.29 Born in 1920, after graduating from the College of Engineering, Guindy, of the Madras University, Mr. T. C. Krishna Rao joined the P.W D. in 1942 In 1956 he was the first Executive Engineer in-charge of buildings constructed at Nagarjunasagar Dam He served also as an Executive Engineer for Inspection and Control. Later, he served as Deputy Chief Engineer, General, P.W D He joined Lal Bahadur Canal Organisation as Superintending Engineer in 1969. He became Chief Engineer, Nagarjunasagar Canals in the year 1971. In the year 1972, he became the Chief Engineer for the entire Nagarjunasagar Project, including the Dam and Canal Construction. After a brilliant record of work, he met premature death before retirement in 1973.

Mr. V. Suryanarayana

17.30 Born in 1917, Mr. V. Suryanarayana took the engineering degree from Madras University in 1939 and joined the P.W D. in 1942. He joined Nagarjunasagar Canals in 1958 as a Superintending Engineer. Later he served as a Superintending Engineer in Srisailam He became Chief Engineer, Nagarjunasagar Canals in the year 1964. He was also Chief Engineer, General of Andhra Pradesh and of Nagarjunasagar Dam and Srisailam Project. During his period of service as the Chief Engineer of Nagarjunasagar, there was good progress on the erection of crest gates. He retired in 1972.

Mr D. Balakrishna Rao

17 31 Born in 1921, Mr. D. Balakrishna Rao took the engineering degree from the Osmania University He joined the Bharat Heavy Electricals and served from 1962 to 1967 as a Project Engineer. Thereafter, he joined as Superintending Engineer, in Lal Bahadur Canal and served there from 1968 to 1970 and became the Chief Engineer for Irrigation in 1972. He took over charge as the Chief Engineer for the entire project of Nagarjunasagar Dam and Canals organisation in 1972. It was in his time that the crest gates of Nagarjunasagar were completed.

Mr A. V. Raghava Raju

17 32 Born in 1921, he graduated from the University of Madras and was the first Executive Engineer in 1957 for buildings and other works on the right flank of the Nagarjunasagar dam. He took keen interest in the construction of Vijayapuri South township and its labour colonies. Later, he joined as the Executive Engineer, Lal Bahadur Canal in the year 1959. He served as Superintending Engineer of Jawahar Canal in 1965 and thereafter he was transferred to the regular construction of the Public Works Department.

Mr B. V. Narasimha Swamy

17.33 He was born in 1922 and took his degree from the University of Madras. He joined Nagarjunasagar dam as the first Executive Engineer of the Bridge and Survey Division in 1956. He was also in charge of the works connected with the roads and buildings of Nagarjunakonda excavations. The unique and magnificent Island Museum of Nagarjunakonda was built by him. Later in the year 1965, he became Superintending Engineer of Lal Bahadur Canal. He met untimely death in 1968

Mr. Rama Murthy

17 34 Born in 1912 he took his diploma in Engineering from the University of Madras He was the Engineer in-charge of the buildings in Vijayapuri South. Later he became the Depuy Chief Engineer of Nagarjunasagar Dam He retired as Executive Engineer in the year 1967 and died in 1969.

Mr Mahmood Hussain

17.35 He was born in the year 1921 and took M S , from Colarado, U S.A in 1948. He joined the dam construction in 1956 as an Executive Engineer He played an eminent role in the construction of the right blocks of the Nagarjunasagar dam from the foundations up to 455 feet level. Apart from his outstanding contribution in the dam construction,

CHIEF ENGINEERS



Mr L Venkata Krishna Iyer—(*Para* 17 19)



Mr. D V Rao—(*Para* 17.18)



Mr M Jafer Ali (*Para* 17 20)



Mr G A Narasimha Rao—(*Para* 17 21)



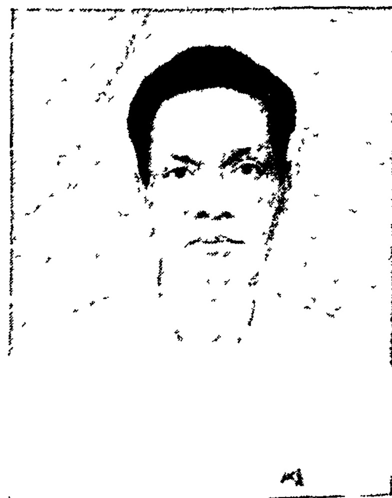
Mr A P Ranganatha Swami—(*Para* 17 22)



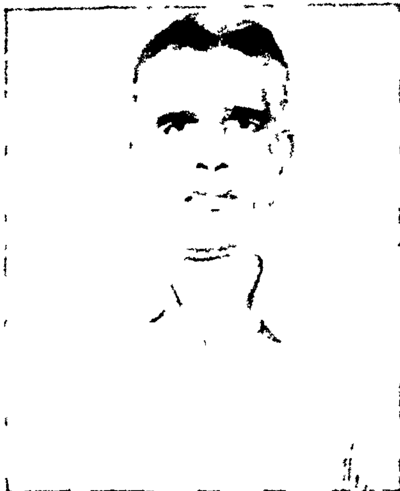
Mr V Suryanarayana—(*Para* 17 30)



Mr T C Krishna Rao—(*Para* 17 29)



Mr D. Balakrishna Rao—(*Para* 17 31)



Mr G K. S Iyengar—(*Para* 17 59)



Mr. V Sree Hari—(*Para* 17 57)



Mr Satnarayan Singh—(*Para* 17 43)



Mr Rahmatullah Khan—(*Para* 17 58)

SUPERINTENDING ENGINEERS



Mr. A R. Chellani—(*Para* 17.23)



Mr. P T Malla Reddy—(*Para* 17 25)



Mr. M A Rahman—(*Para* 17 24)



Mr. K. V. Sreenivasa Rao—(*Para* 17.26



Major . M Rangaswamy—(*Para* 17 27)

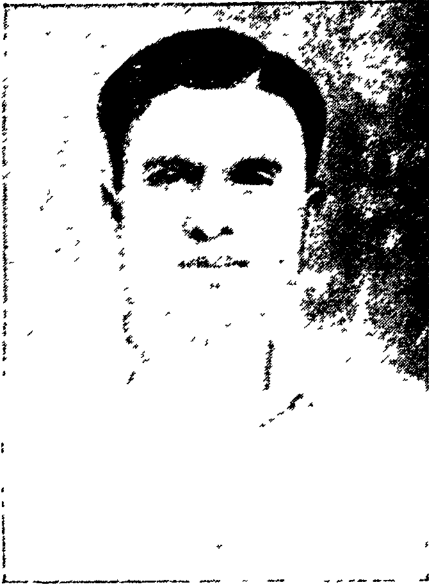


Mr K Ramabrahmam—(*Para* 17 28)



Mr N Venkatesam—(*Para* 17 64)

EXECUTIVE ENGINEERS



Mr. K. R Chary—(*Para* 17 44)



Mr Mahmood Hussain—(*Para* 17.35)



Mr S Balasubramanyam—(*Para* 17 36)



Mr. P. V. Rao—(*Para* 17 37)



Mr R C Rao—(*Para* 17 38)



Mr P R G Reddy—(*Para* 17 39)



Mr G K Reddy—(*Para* 17 40)



Mr D. Rajendra Kumar—(*Para* 17 63)



Mr. M Sreerami Reddy (*Para* 17.42)



Mr G. V. Narsimham—(*Para* 17 45)



Mr. T K Mohan Rao—(*Para* 17 47)



Mr M Bhasker Rao—(*Para* 17 50)

he took keen interest in social and labour welfare. He was made the Superintending Engineer for the Special Drainage Circle, of Andhra Pradesh in 1965 He became the Managing Director of Andhra Pradesh Irrigation Development Corporation in 1974

Mr S Balasubrahmanyam

17.36 Mr. S. Balasubrahmanyam was born in 1922 After his close association with the construction of Hirakud dam, he joined as a Specialist Executive Engineer in the dam in 1956. He ably organised and built the Laboratory and played an effective role to maintain the quality of works. After serving for six years in the organisation, he joined the Central Water and Power Commission, Government of India as Director. Later, he became the Chief Engineer, WAPCO in the year 1972 Later he was deputed on a foreign assignment to the Government of Zambia as a Principal Civil Engineer.

Mr P. V. Rao

17 37 Born in 1922, he took his Engineering degree from the University of Madras and M S from the University of Colorado, U S.A After serving the Bhakra Dam Designs Organisation, he joined the Nagarjunasagar dam as a specialist Executive Engineer in 1956 in-charge of designs He was responsible for the detailed designs of the dam from 1961 to 1964. He served as the Deputy Chief Engineer and then took over as Executive Engineer Earth Dam and Safety Division In his time the diversion tunnel with an intake structure was completed and the Right Earth Dam was built in a record time He was made Superintending Engineer in-charge of Earth Dams and Diversion Tunnel in 1965. After working efficiently for 11 years, he left the dam organisation in the year 1967 and became the Superintending Engineer in-charge of the Guntur Circle of Jawahar Canal. He became Chief Engineer in 1978 and retired.

Mr. R C. Rao

17.38 Born in 1923, Mr. R. C. Rao graduated from the University of Madras. After serving in Hirakud dam Project, he joined Nagarjunasagar dam as a Specialist Executive Engineer in 1956. He was in-charge of left earth dam and foundation treatment for the entire dam. The construction plant for compressed air equipment and water pumping plant for the dam works were planned and put up by him. After an outstanding work of 8 years in the dam construction, he left for Srisailam where he worked as Superintending Engineer from 1964. In the year 1972 he left Srisailam and became Superintending Engineer for the construction

of Dowlaiswaram Barrage, an important hydraulic structure across the Godavari river. In 1974 he was elevated as the Managing Director of the Andhra Pradesh State Construction Corporation Limited, where he played an eminent role in building up a Public Sector Construction Organisation As Chief Engineer, he retired in 1978.

Mr. P R. G. Reddy

17 39 He was born in 1921 and graduated from the University of Madras He was the first Executive Engineer in-charge of the quarrying operations and materials supply, which he organised efficiently. He joined Srisailam project as a Superintending Engineer and became the Chief Engineer of the Project in the year 1973. He served as the Chief Engineer of Minor Irrigation for the entire Andhra Pradesh and retired in 1976. He was noted for his peerless qualifications for management and enforcement of discipline.

Mr. G K Reddy

17.40 Born in 1924, he graduated from the University of Madras in 1948. He joined the dam organisation in 1957 as an Executive Engineer. He worked efficiently in various divisions of Safety, Heavy Machinery Transport and Workshop. He became Superintending Engineer, Mechanical Circle of the Project in the year 1964. He played an eminent role in planning and organisation of various mechanical units of Nagarjunasagar Project. In 1975, he was elevated as the Managing Director of Republic Forge, a public sector undertaking of Government of Andhra Pradesh He became Chief Engineer in the P.W.D. in 1978.

Mr C Sanjeeva Rao

17.41 Born in 1914, Mr. C. Sanjeeva Rao graduated in Mechanical Engineering from the College of Engineering, Guindy, Madras University. After designing, manufacturing and erecting the gates of Prakasam Barrage at Viyayawada, Andhra Pradesh and serving the Srisailam Project, he joined Nagarjunasagar Dam as Superintending Engineer and served from 1967 to 1969. During his time, the first crest gate was erected and tested He manufactured departmentally roller and rocker bearings for the spillway bridge and trash racks.

Mr. M. Sreerami Reddy

17.42 Born in Cuddapah in 1928, he graduated from the University of Madras He joined as an Assistant Engineer for designs in the Nagarjunasagar Dam. He was promoted as Deputy Chief Engineer for Administration in the year 1961 and then took over charge as Executive Engineer for the construction of the right bank portion of Nagarjunasagar

Dam in 1964. He managed the works excellently and brought the dam from 455 feet level to the completion level. After an outstanding record of service in dam construction for 13 years, he joined the Srisailam Project as Executive Engineer for Designs. In the year 1972 he was selected as Director, Designs of Dams in the Central Water and Power Commission on account of the expertise he had developed. In 1975, he became Superintending Engineer Designs in the State of Andhra Pradesh. He built the Sri Rama temple near the right flank of the dam

Mr. Satnarayan Singh

17.43 Born in 1925, he graduated from the Osmania University. After serving for nine years in the regular Public Works Department, he joined the organisation of the dam as the Deputy Chief Engineer in 1957. In the year 1958 he took over charge of the Materials Division and played an eminent role for timely and efficient supplies. He was promoted as Superintending Engineer of the Tungabhadra Control Board and later became the first Managing Director of the Andhra Pradesh State Construction Corporation in 1973. He laid strong foundations of this public sector undertaking, the first of its kind in the State of Andhra Pradesh. In 1973, he became the Chief Engineer, Nagarjunasagar Left Canal. In his time the Canal Construction was organised magnificently.

Mr K R. Chary

17.44 Born in 1912, he graduated from the College of Engineering, Guindy, Madras He joined Nagarjunasagar dam in 1956 as the first Mechanical Executive Engineer. He organised water supplies, heavy machinery, stores, transport, batching plants and electrification at the initial stages of the project He was a dynamic and brilliant Engineer, who managed the works efficiently for six years He was made the Superintending Engineer-in-charge of Central Mechanical Unit in 1963 at Hyderabad. After a meritorious service, he met premature death in 1967 due to heart attack He was reputed for his sterling character.

Mr. G. V. Narasimham

17.45 He was born in 1928 and graduated from the University of Andhra. Afer playing an eminent role as Mechanical Assistant Engineer in Nagarjunasagar Right canal, he joined the organisation of the dam as Executive Engineer, Mechanical in 1964 All the gates of the dam were erected by him. For some time he was also in-charge of heavy machinery. After his outstanding work from 1964 to 1970 he joined the Srisailam Project After serving there for one year he joined the Ahdhra Pradesh State Agro-Industrial Corporation Limited, as Regional Manager. In 1973 he took over charge as the General Superintendent of Seethanagaram Workshop at Vijayawada.

Mr. Asoke Kumar Mukherjee

17.46 Born in 1940, Mr. A K. Mukherjee took his B.Sc. (Hons.) in Civil Engineering from the University of Glasgow (U.K.) in 1961, with his brilliant career abroad and experience in structural designs, he joined the out-standing gates and structural manufacturers M/s. Jessop & Co., Ltd., Calcutta in 1962 The firm supplied the radial-gates for Nagarjunasagar dam. Mr. A. K. Mukherjee as their structural engineer, completed the erection of the gates in a record time of two years. All the 26 gates measuring 45′×44′ gave satisfactory test of performance.

Mr T. K. Mohana Rao

17.47 Born in 1924, he graduated from the University of Madras, College of Engineering, Guindy. He joined the construction of the dam as an Assistant Engineer in the year 1956 and became Deputy Chief Engineer in 1959. In 1947 he had taken over charge of the construction of Labour Camps and departmental production of rubble. From 1964 to 1968, he was in-charge of construction of left half of the dam. After a brilliant career of 12 years in association with the dam, he became Superintending Engineer for Jaggaiahpet Circle of Lal Bahadur Canal In the year 1972 he was transferred to Pochampad Project. In 1977 he became Chief Engineer for Minor Irrigation works of Andhra Pradesh.

Mr. Y. P. C. Choudary

17.48 Born in 1927, he graduated from Engineering College, Kakinada of Andhra University. He joined Nagarjunasagar dam in 1955 and was in-charge of quarries. He became Executive Engineer, Materials Division in 1964. He was responsible for controlling contractor's rates by organising a parallel departmental quarrying unit. Later he took charge of construction of the dam and completed the spillway, utility towers, spillway bridge, railings and the entire architectural features. At the completion of the dam he was in-charge of the maintenance of the gigantic structure. His dedication and zeal effectively contributed to the materialisation of the project right from the beginning to the end.

Mr. K. V. Suryanarayana Murthy

17.49 Born in 1920, he passed A.M.I.E. (India) examination in 1953. He worked assiduously in the Project of the dam for 6 years and was in-charge of the inspection and control and later, was also in-charge of construction. In the Nagarjunasagar dam laboratory he improved the aerosin, air entraining agent. He did excellent work in the construction of belt conveyors for carriage of concrete and in the completion of the spillway bridge.

Mr. M. Bhasker Rao

17 50 Born in 1921, he passed A.M I E. (India) examination in 1950. He worked in Nagarjunasagar dam works from 1962 to 1969. He was a methodical and capable Executive Engineer of inspection and control and he also worked in instrumentation in the dam and rehabilitation works Later he served as an Executive Engineer in Srisailam Project and became Superintending Engineer in 1976

Mr. P. F. Moses

17.51 Born in 1921, he graduated from the University of Madras He had worked in Electricity Department before he joined the project as Executive Engineer. He worked at the dam from 1961 to 1963. He was responsible for departmental erection of penstock pipes in record time and for the successful closure of the construction sluices. He was known for his tenacious and talented work. After Nagarjunasagar he was posted to Srisailam works where he died prematurely in 1974.

Mr. Misbahuddin Khan

17.52 Born in 1915, Mr Misbahuddin Khan, graduated in Electrical Engineering from the University of Aligarh. He served as an Executive Engineer in-charge of electrification and electrical installations for ten years. He rendered yeoman services for the materialisation of the project Apart from his engineering field, he was taking keen interest in the health and welfare of the people. He was assisted by the Assistant Engineers, M/s. V. S. Sivaram, N Satyanarayana, G. Munuswamy Naidu, Azam Pasha, A. V. Satyanarayana Rao, G Chiranjeeva Rao, T.V S Prakasa Rao, C. Seshadri and N. Suryanarayana, who did very good work.

Mr. K. Rama Rao

17.53 He was born in 1929 and took his engineering degree from the University of Andhra. In his early career as an Assistant Engineer, he did outstanding work in the manufacture of gates of Prakasam Barrage He was the Executive Engineer, Mechanical Division from 1965 to 1969 He organised the transport system, operation of cranes and locos efficiently that helped to accomplish high targets in construction Later he was posted as Executive Engineer in Jaggiahpet circle of Left Canal of Nagarjunasagar, where he died prematurely.

Mr. E. Floate

17.54 A practical man, rose from the rank of a fitter to an Executive Engineer by virtue of hard, sincere and intelligent work. He had impressed all engineers with his ingenuity and intelligent work He joined Nagarjunasagar dam as a General Superintendent of workshop in the year 1962 and worked till 1967. He was assigned the task of fabrication

of the trestle bridge, stoplogs, trash racks, which he executed excellently. He manufactured in the workshop two Diesel launches, named Vijaya Laxmi and Bhanu. After a distinguished service in Nagarjunasagar dam he retired in 1967 and passed away in 1972.

Mr. V. Somasankara Rao

17.55 He was born in 1927 and had taken his engineering degree from Annamalai University He worked in the construction of the dam as Executive Engineer from 1961 to 1968. He was in-charge of batching plants, punts and mono-tower cranes and managed very efficiently. He was responsible for the attainment of high targets of construction Apart from his key role in the construction of the dam, he established very efficient Co-operative Society ' Sangha Mitra ' which had served the people for a number of years.

Later he was transferred to Srisailam where he played an eminent role as the Superintending Engineer of construction.

Mr. D. L. N. Raju

17.56 Born in 1924, Mr. D. L. N. Raju, as Executive Engineer eminently participated in early stages of the Project both in building construction and preparation of foundations of the dam. Later, he efficiently contributed in the construction of the canals as Superintending Engineer With his yeoman services and brilliant career, he joined the Pochampad Project as Chief Engineer in 1977.

Mr. V. Sree Hari

17.57 Born in 1924, Mr V. Sree Hari graduated in engineering, from Madras University. After serving for 10 years in the Tungabhadra Project and as Superintending Engineer in Nagarjunasagar, he took over as the Chief Engineer, Nagarjunasagar Dam and Right Canal in 1976 During his time there was phenomenal progress in the construction of the Right Canal under his outstanding guidance and planning.

Mr. Rahmatullah Khan

17.58 Born in 1926, Mr. Rahmatullah Khan graduated in civil engineering in 1947 from the Guindy Engineering College of Madras University. With his rich experience of construction of irrigation and power projects of Srisailam and Kothagudem, he took over as the Chief Engineer of Left Canal in 1978. The Left Canal made record progress under his dynamic leadership.

Mr G. K S. Iyengar

17 59 Born in 1922, Mr. G K. S. Iyengar graduated in engineering from Osmania Engineering College. With his wide experience in

designs and construction of Irrigation and Power projects, he took over as the Chief Engineer of Nagarjunasagar Project in 1975. Under his able guidance, there was marked progress in the construction of canal After a glorious service he retired in 1977.

Mr. G N V Koppa

17 60 Born in 1925, Mr G N V Koppa, graduated from the Engineering College of Mysore in 1947 He joined the organisation as an Executive Engineer in-charge of the Mechanical Division where he worked from 1960 to 1965 The first monotower crane was erected during his time. He managed this work efficiently in various sections as in-charge of heavy earthmoving machinery, workshop, gates and penstocks Later he joined the same organisation as Superintending Engineer of Mechanical circle

Mr. N. Ramachander Rao

17 61 Born in 1913, Mr N. Ramachander Rao, took his diploma in Civil Engineering from the Guindy College of Madras He joined Nagarjunasagar dam in the year 1955. He was the first Assistant Engineer who had started the excavation of the dam on the left flank and he also started the masonry when S K Patil laid the first masonry stone. He built the masonry coffer dam in record time Later in the year 1962 he was promoted as Executive Engineer in the Public Works Department. He retired in 1968.

Mr C Janardhan Rao

17 62 A holder of Master's degree in Engineering from the University of California, Mr C. Janardhan Rao served efficiently the organisation as an Assistant Engineer in-charge of the dam construction in the year 1956 and left in 1958 He became Executive Engineer in the regular P W D in 1960 and Superintending Engineer in 1973 He had played an eminent role in the Pochampad Project as Superintending Engineer in-charge of the dam construction.

Mr. D. Rajendra Kumar

17.63 Born in 1931, Mr Rajendra Kumar, took his engineering degree from the University of Iowa. He joined the Nagarjunasagar Investigation Division in 1954 as an Assistant Engineer and later organised the Field Workshop at the site of the dam which proved very useful for the dam construction After an illustrious record of shuttering and concreting in the dam construction, he joined Srisailam dam as Executive Engineer where he had tackled the difficult work of constructing the coffer dam across the Krishna river. He was promoted as the Superintending Engineer in-charge of the Mechanical Circle, Nagarjunasagar in the year 1973.

Mr. N. Venkatesam

17.64 Born in 1927, Mr. N. Venkatesam, took his degree in engineering from the Osmania University. He was Assistant Engineer in Dam construction in the year 1956 and was in-charge of Inspection and Control where he worked efficiently. He served as Executive Engineer of the township from 1960-61. He was deputed to U.S.A. for training in Bureau of Reclamation, Denver. He took over as Superintending Engineer for the maintenance of Nagarjunasagar Dam in 1974.

Mr. M. Tirupath Reddy

17.65 Born in 1927, Mr. Tirupath took his engineering degree from the Osmania University. He joined the Nagarjunasagar dam construction as Junior Engineer in 1956 for designs. He was Assistant Engineer from 1957 to 1961 and served in preparation of foundations, concreting, masonry and mortar and rubble distribution. He was mainly responsible for the left bank foundation excavations in difficult stages of construction. He was promoted as Executive Engineer in the P.W.D. out of turn in 1965, due to a brilliant and outstanding career. Later, he joined the Andhra Pradesh State Construction Corporation in 1974 where he was elevated as Project Engineer to build the Srisailam dam, the biggest hydro power station of Andhra Pradesh.

Mr. J. Satyanarayana

17.66 Born in 1929, Mr. J. Satyanarayana graduated in Engineering from the Osmania University. He joined the dam construction in 1956 as Junior Engineer. As an Assistant Engineer he served from 1958 to 1961 in various divisions in surveys, designs, inspection and control and in construction, with a brilliant record of work. He was made the Executive Engineer of the Lal Bahadur Canal in 1970.

Mr. K. M. Mohd. Siddique

17 67 Born in 1935, he graduated from the Osmania University. A brilliant scholar of his time, he worked as an Assistant Engineer in right flank of the dam from 1960 to 1967. He was reputed for his sincere and hard work.

Mr. Venkatapathi Raju

17.68 He served the Nagarjunasagar dam for eight years. As an Assistant Engineer, he was in-charge of raising the Right Earth Dam from the start of the foundation till completion He worked strenuously round the clock.



Mr. P F. Moses—(*Para* 17 51)



Mr G. N. V Koppa—(*Para* 17 60)



Mr. Ramamurthy—(*Para* 17.34)



Mr Y. P. C Chowdary—(*Para* 17 48)



Mr. K. V. Suryanarayana Murthy
(*Para* 17.49)



Mr. Misbahuddin Khan—(*Para* 17.52)



Mr. E. Floate—(*Para* 17.54)



Mr. S. K. S. Iyengar—(*Para* 17.78)



Mr. D. L N. Raju—(*Para* 17 56)

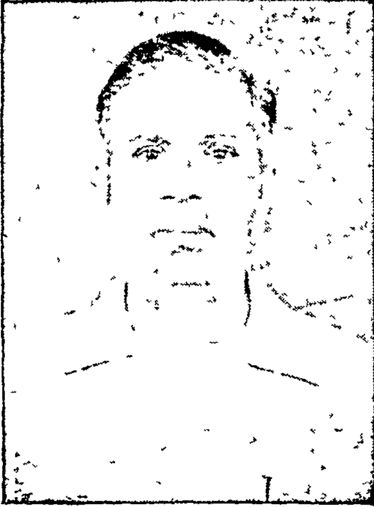


Mr. V Soma Shaker Rao—(*Para* 17.55)

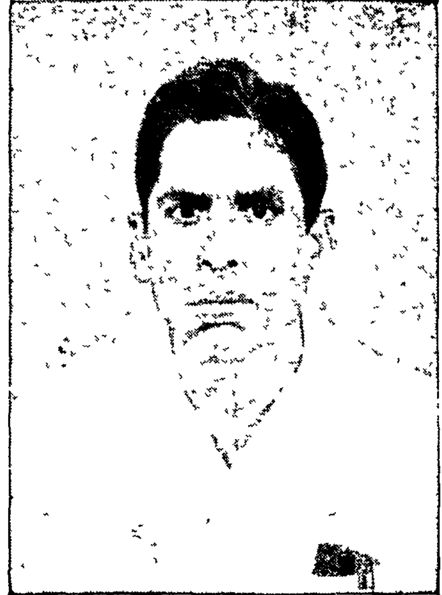


Mr. Rajaiah Raj—(*Para* 17.102)

ASSISTANT ENGINEERS



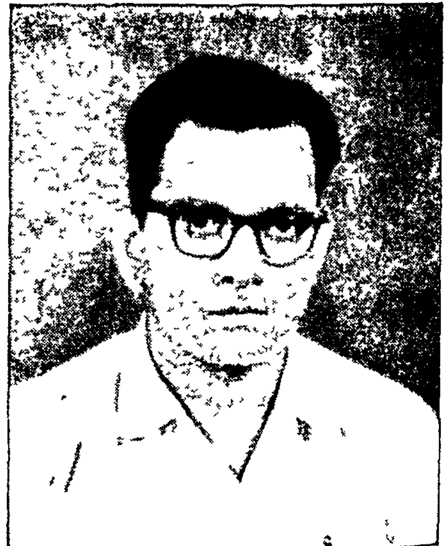
Mr C. Janardhana Rao—(*Para* 17.62)



Mr. M. Tirupath Reddy—(*Para* 17.65)



Mr. S V Sastry—(*Para* 17.72)



Mr. C. L. N. Sastry—(*Para* 17 85)



Mr K. M. Mohd. Siddique—(*Para* 17 67)



Mr. P Sreenivasulu—(*Para* 17 79)



Mr. C. Venkateshwarlu—(*Para* 17.87)



Mr K. Kishan—(*Para* 17 89)



Mr S. S R. Sastry—(*Para* 17.91)



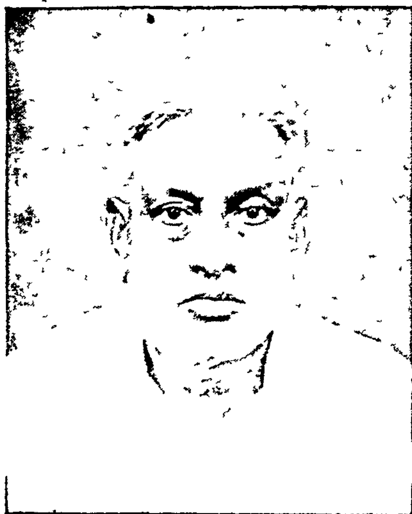
Mr A. Ramachandra Rao—(*Para* 17,94)



Mr P. Krishnam Raju—(*Para* 17 96)



Mr. K. Radha Krishna Murthy—(*Para* 17,97)



Chiranjeevi Rao—(*Para* 17 98)



Mr B. S. Murthy—(*Para* 17 101)



Mr M Rangaiah—(*Para* 17.5)



Mr. Mohammad Shujat Ali—(*Para* 17 103)



Mr Anjaneya Sastry—(*Para* 17 10[illegible])



Mr S S Quadri—(*Para* 17.106)



Mr. A. K. Mukherjee—(*Para* 17.46)



Mr Ratnakar Rao—(*Para* 17.5)

Mr. S. Krishnamachary

17.69 Born in 1929, Mr. S. Krishnamachary, graduated from the Engineering College of Osmania University. He served as an Assistant Engineer for nearly ten years in construction and inspection He was dutiful and sincere in giving high targets Later, he became Executive Engineer in the P W.D. and met premature death in 1977.

Mr. T. Rajaram

17.70 He was born in 1929 and took the engineering degree from the Osmania University. He joined Nagarjunasagar in 1958 as Assistant Engineer and was in-charge of shuttering and concreting He managed the field workshop for the shuttering with superb performance. Later, he was made the Executive Engineer in-charge of Farakka Barrage Construction having been selected by the Union Public Service Commission.

Mr. B. Rangaiah

17.71 Born in 1925, Mr. B. Rangaiah, graduated from the Osmania Engineering College, he joined the Nagarjunasagar dam organisation as an Assistant Engineer. Later, he was promoted as Executive Engineer in regular P.W.D. He was in-charge of the dam construction where he did good work.

Mr. S. V. Sastry

17.72 Born in 1934, Mr. S. V. Sastry graduated from the Engineering College of Osmania University. As an Assistant Engineer with dedication to his duties, he had worked in various wings of the construction such as approach road to the dam, civil works of the batching plants, shuttering, concreting and masonry construction, etc On account of his outstanding work, he was given the Division charge for concreting the Right Canal Sluices, which he carried out in record time. As one of the chief builders, he had to face difficult circumstances and served exceedingly well at the sacrifice of personal comforts He worked on the project for 17 years from investigations of foundations to completion and became Executive Engineer in Lal Bahadur Canal for Nadigudam Division in 1972. In 1974, he joined the Andhra Pradesh State Construction Corporation as Zonal Engineer and was elevated as Project Engineer in recognition of his peerless and outstanding services.

Mr. B. Sowri Reddy

17.73 Mr. Sowri Reddy worked at the dam for ten years in concreting and masonry construction He was very industrious and a practical engineer. He was responsible for high targets in the construction programme.

Mr P. Rama Raju

17.74 He worked in masonry and concreting for 8 years. He was in-charge of raising right flank blocks. He worked strenuously and kept up high progress in construction.

Mr. C. Satyanarayana

17 75 Worked as an Assistant Engineer for five years and managed mortar supply arrangements efficiently for five years. He contributed for achieving high targets.

Mr. Y. Venkateshwara Rao

17.76 As an Assistant Engineer he served for 8 years and tackled the foundations of the right flank in record time. Later he worked in the rehabiliation. He was reputed for his dedicated services.

Mr. V S. Ganapathy Ram

17 77 He was the first Electrical Assistant Engineer of the Project, who did pioneer work for laying transmission lines, telephone lines and procurement of electrical materials. Later, he became Executive Engineer in the Electricity Department and was promoted as Superintending Engineer in the year 1970 and became the Chief Engineer in 1974.

Mr. S. K. S Iyengar

17.78 He was born in 1924 and graduated from the Osmania University. He served the dam as an Assistant Engineer from 1958. He did outstanding work in the Inspection and Quality Control of the Project and dam construction. He was made Executive Engineer in regular P.W.D. in 1971. He was reputed for his all round capabilities in construction and quality control. Later, his outstanding and precious services were utilised by the Andhra Pradesh State construction corporation

Mr. P. Sreenivasulu

17.79 Born in 1932, he took the engineering degree from Andhra University. He started his career in 1957 as Junior Engineer in Nagarjunasagar dam construction from foundation excavation. He became Assistant Engineer in 1964. He was responsible for concreting the copper sealing strips, departmental manufacture of steel form-work for penstocks, trashracks and galleries. He carried out the works of the spillway bridge piers, parapet walls and architectural features At the completion of the dam, he was entrusted with the maintenance works. His devoted, diligent work and outstanding sense of duties enabled the project to keep to the high targets.

Mr T. Hanumantha Rao

17.80 He was born in 1930 and took the engineering degree from the Andhra University. He was the pioneer to design and construct protected water supply and sewerage systems to the various camps. Prompt and vigilant in work, the supplies never failed during his tenure. He became Executive Engineer in regular P.W D. in 1963 and Superintending Engineer in 1978.

Mr Prabhakar Rao

17 81 Born in 1929, graduated from the Andhra University, he joined the organisation as an Assistant Engineer for water supply and drainage. He managed the sanitary installations ably. After yeoman services to the dam he became Executive Engineer in Canals.

Mr. A. V. Appa Rao

17 82 Mr. A. V. Appa Rao, was born in 1924 and graduated in Engineering from the Andhra University. He worked as an Assistant Engineer for water supply and drainage works and managed his unit efficiently. He played an active role in the social activities of the project. After dedicated services in dam, he became Executive Engineer of Dowlaiswaram Barrage Construction.

Mr Sheik Dawood Sharief

17.83 Born in 1930, Mr. Shaik Dawood Sharief graduated from the Engineering College, Andhra University. He joined the dam construction as an Assistant Engineer. He managed the construction of the famous Island Museum and the colonies at Nagarjunakonda. After completing the museum works, he was in charge of the Right Earth Dam. He did his job efficiently.

Mr. Mohammed Ali

17.84 Mr. Mohammed Ali was born in 1937 and graduated from the Osmania University. As an Assistant Engineer, in-charge of the masonry and concreting of Right Flank of Nagarjunasagar dam, he discharged his duties with a high degree of sincerity and devotion

Mr. C. L. N Sastry

17.85 Born in 1934, Mr. C L N. Sastry, obtained the degree in Engineering from the Osmania University. As an Assistant Engineer, he managed very efficiently the masonry construction of the right flank of the dam from its foundations till completion. He was in-charge of various works, such as civil works of batching plants, workshops, shuttering, reinforcement and concreting of galleries. He was a popular engineer, who took keen interest in the activities of the club in cultural and social

functions. He did outstanding work in the Nagarjunasagar Dam from 1959 to 1970. Later, he was made Executive Engineer in the regular P W.D In 1977, he joined the Andhra Pradesh State Construction Corporation as a Zonal Engineer of Pochampad Canal Construction works Due to his outstanding and strenuous work he was later elevated as the Project Engineer.

Mr. Basavaiah

17.86 Born in 1929, he graduated in engineering from the Andhra University. He was the first Junior Engineer in-charge of the masonry coffer dam on the left flank of the dam. He completed this job in record time. Later, he became an Assistant Engineer in 1961. He managed works efficiently in various divisions, and became Executive Engineer in the construction of Srisailam Dam.

Mr. C. Venkateshwarlu

17.87 Born in 1932 Mr. C. Venkateshwarlu, graduated from Kakinada Engineering College of Andhra University. He started as a Junior Engineer in the construction on the masonry coffer dam which was built in a record time. He worked in the project from 1956 to 1963. He played an active and devoted role in the excavation of the foundation of the dam. Later he became Executive Engineer in the regular P.W.D.

Mr. T Narasimha Murthy

17 88 A graduate from the Andhra University, Mr. T. Narasimha Murthy joined the dam construction as a Junior Engineer in the excavation of the foundation of the dam. He was responsible for high records of construction. He worked with great devotion day-in and day-out at the cost of his health. He became an Assistant Engineer in the Lal Bahadur Canal in 1972.

Mr. K. Kishan

17 89 Born in 1934, Mr. K. Kishan graduated from the Osmania University. He joined the dam construction as an Assistant Engineer in 1960. He carried out the construction of the masonry dam very efficiently with devotion. He was also associated with the markouts of the dam and appurtenant works. He became Executive Engineer in the regular P.W.D. in the year 1972.

Mr. N. Narasimha Murthy

17.90 Mr. N. Narsimha Murthy, worked as an Assistant Engineer for five years. He took active part in the various construction works of the dam and buildings.

Mr. S. S. R. Sastry

17.91 Born in 1923 Mr S. S R Sastry, is a diploma holder in Civil Engineering He mastered the maintenance of light vehicles and was in-charge of them in Nagarjunasagar Dam from 1962 to 1968 After an excellent record of eight years of service in the dam, he left the project and became Deputy Director, Water Resources and Designs at Hyderabad.

Mr. K Krishnaiah Chetty

17.92 Born in 1925, had his graduation from Andhra University. He was an Assistant Engineer in-charge of the quarries and track lines for light railways He managed the operations efficiently. He became Executive Engineer in 1965.

Mr. R. Venkateswara Rao

17.93 He joined the dam construction as an Assistant Engineer and worked in various sections of the dam construction, such as foundations, concreting and masonry. He was a great devoted engineer who worked day-in and day-out diligently at the sacrifice of his health, for the materialisation of the project. With a brilliant record of service, he became an Executive Engineer in Jawahar Canal in 1972.

Mr. A. Ramachandra Rao

17.94 Born in 1926 Mr. A Ramachandra Rao had his engineering degree from the Andhra University. He joined the dam construction as an Assistant Engineer in 1962 He was in-charge of the masonry work and maintained an efficient and good record of service. He became an Executive Engineer of the regular P.W.D. in 1965 and later took over charge of the maintenance of Right Canal at the head reach

Mr. M. C. V. Raju

17.95 Born in 1929, Mr M C V Raju took his engineering degree from the Andhra University. He was the first Assistant Engineer of Inspection and Control Organisation He was an efficient and punctual engineer and worked with scrupulous devotion to his duties.

Mr. P. Krishnam Raju

17.96 Born in 1930, Mr. Krishnam Raju graduated from the College of Engineering, Guindy, Madras University. From 1957 to 1965 he worked as an Assistant Engineer in-charge of various works, in designs, earth dam, buildings and masonry. He became Executive Engineer in 1965. From 1965 to 1968 he was in charge of the diversion tunnel and the right earth dam. As an efficient and devoted engineer, he was responsible for high targets of construction

Mr K. Radha Krishna Murthy

17.97 Born in 1931, Mr. Radha Krishna Murthy, took his Electrical Engineering graduation from Madras University. He worked as an Assistant Engineer for Electrical works and telephone lines, assiduously and efficiently. After working from 1961 to 1972, he was transferred to the Andhra Pradesh Electricity Board where he became Executive Engineer.

Mr. Chiranjeevi Rao

17.98 Born in 1919, Mr. Chiranjeevi Rao, took diploma in Electrical Engineering in 1941. He worked at the dam for nearly 12 years as an Assistant Engineer and managed all electrical installations on the right bank. He was responsible for prompt and perfect performance of the system.

Mr Abhi Rameshwar Rao

17.99 Abhi Rameshwar Rao, joined the dam as Junior Engineer and was promoted as Assistant Engineer. He was in-charge of all the electrical works connected with the lighting of the dam and running of electrical machinery He never gave room for any complaints in his section

Mr. B Ramachandra Rao

17 100 Born in 1923, Mr. B. Ramachandra Rao took the diploma in engineering from the Madras University. He worked as a Mechanical Executive Engineer in-charge of heavy machinery. He held the charge of the Stores from which he supplied materials promptly. He took interest in social work with his poetic talent.

Mr. B. S. Murthy

17 101 Born in 1927, served Nagarjunasagar dam as a supervisor from 1956 and as an Assistant Engineer in-charge of buildings and stores from 1963 to 1970. He was a very conscientious and devoted engineer. He worked strenuously and took interest in sports and club activities

Mr. Rajaiah Raj

17.102 Born in 1927, Mr Rajaiah Raj, had his graduation from the Osmania Engineering College He served the dam construction as an Executive Engineer from 1965 to 1967 and was transferred to Lal Bahadur Canal in 1968. As an efficient engineer he was responsible for high and unparalleled targets of concreting in the Jawahar Canal Regulators. Later, he became Superintending Engineer in Lal Bahadur Canal.

Mr. Mohammad Shujat Ali

17.103 Born in 1922, he took his diploma in engineering from the Osmania University He was a brilliant scholar. He joined the dam construction as an Assistant Engineer and served from 1955 to 1960 He managed the batching plant supplies very efficiently and promptly which were mainly responsible for high targets of construction. He left the project in 1970 and joined the regular P.W.D where he became Executive Engineer. After retirement in 1977 he joined the Andhra Pradesh State Construction Corporation as a Zonal Engineer

Mr. B Sultan Saheb

17.104 He was born in 1929 and took his degree in Engineering from Andhra University. He was an ardent Assistant Engineer in-charge of various works of maintenance and running of earth-moving machinery, transport and workshop. He was popular among the staff and managed his section very efficiently. He served in the project for 14 years from 1956 to 1970. Later, he became Executive Engineer at Srisailam Dam Construction.

Mr. Anjaneya Sastry

17.105 Born in 1935, Mr Anjaneya Sastry was a brilliant scholar of the Andhra University. He was associated with the designs of the dam for 13 years from 1956 to 1969. He joined as Junior Engineer and was promoted as Assistant Engineer in 1961. He had contributed to the timely and successful completion of the right canal head regulator, right power house blocks, chute sluice on the right bank and the spillway crest He was promoted as Executive Engineer of the Central Designs Organisation.

Mr. S S. Quadri

17.106 Born in 1935, Mr S S Quadri, graduated from the Engineering College of Osmania University in 1957 He worked in Nagarjunasagar as an Assistant Engineer from 1964 to 1969 in the crucial stages of construction. He was on the operation of crushing and screening plant. He was singly responsible for completion of the walkway in a record time. He was a conscientious, devoted and dynamic engineer, who worked at the cost of his health. Later, he joined the Andhra Pradesh State Construction Corporation, as the Zonal Engineer in-charge of Lower Manair Dam Construction.

Mr. M Nagabhushana Rao

17 107 Born in 1932, Mr M. Nagabhushana Rao took the engineering degree from the University of Madras He worked at the dam from 1959 to 1968 During this period he did outstanding work in hydraulic research, field and laboratory testing of mortar and concrete and in the designs.

Accounts Officers

17 108 Mr. A L Saksena was the first Financial Adviser and Chief Accounts Officer, who did original work in the organisation for adopting the pre-audit system from 1956 He was suceeded by Sri S. Ramaiah who worked from 1958 followed by Sri P. V. Raghava Rao, a retired Accountant General of Central Revenues. Sri P. V. Raghava Rao made some drastic changes in reducing the number of estimates of the dam of various blocks and for prompt payments. Mr. M. A. Laxman succeeded Sri P. V. Raghava Rão and retired in 1970, and Sri S. Ramier took over charge from him and was responsible for the payments of several final bills, held up due to various objections. He was followed by Mr. Suryanarayana, Mr. Shankara Guruswamy, Mr. K. V Natarajan, Mr. Veera Raghavan and Mr. Raghavan.

17.109 The following Deputy Chief Accounts Officers and Pay and Accounts Officers, assisted the Financial Adviser and Chief Accounts Officer for payments and maintenance of accounts.

Mr K. S Murti ..	Deputy Chief Accounts Officer.	1956 to 1958
Mr. K. N. Rao .	do.	1958 to 1960
Mr. C. P. Wanchoo ..	do.	1960 to 1963
Mr. P. A. Seshan ..	do.	1963 to 1968
Mr. Ganeshan ..	do.	1968 to 1969
Mr. R. Chandra Sekharan	Dy. Chief Accounts Officer.	1969 to 1972
Mr. Anantachary ..	Pay and Accounts Officer.	1955 to 1958
Mr. Iftekhar Hussain .	do.	1958 to 1962
Mr Ashraf Hussain .	do.	1962 to 1967
Mr. Kameshwar Rao	do.	1967 to 1969
Mr. Gani Raju ..	do.	1969 to 1972
Mr. B. P. Sastri ..	do.	1972 to 1974
Mr. Chintaman Rao..	do.	1966 to 1968
Mr. Karumbeshwaran.	do.	1968 to 1970
Mr. T. Laxminarayana	do.	1967 to 1970

Work-Charged Employees

17.110 The Work-charged staff played vital roles in the timely and successful completion of the project. Some of the work-charged-staff rendered yeoman services and were awarded gold medals, for their

DOCTORS



Dr M Rama Sheshaiah—(*Para* 17 115)



Dr T Rangiah—(*Para* 17 116)



Dr Suryaprakasa Rao—(*Para* 17 117)

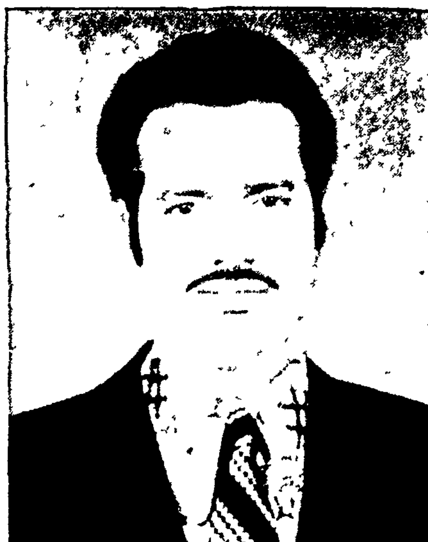


Dr T B G Tilak—(*Para* 17 118)

CONTRACTORS



Mr Chandrasekhar Reddy, T —(*Para* 17 123)



Mr Krishna Reddy, G V —(*Para* 17 125)



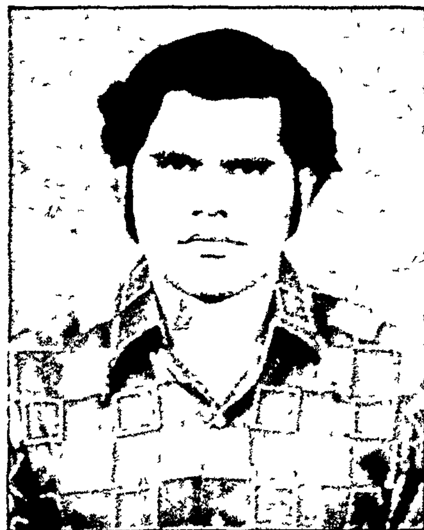
Mr Nageshwar Rao, V —(*Para* 17 126)



Mr. Zamin Ali Gazi—(*Para* 17 133)



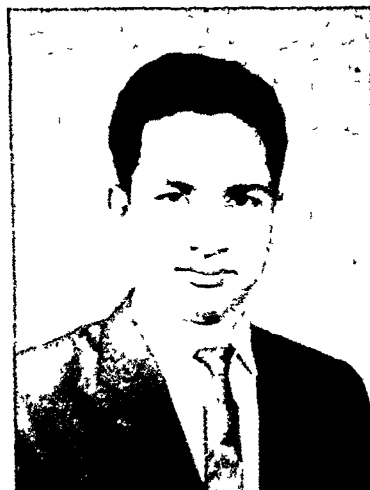
Sagı Ramakrıshnam Raju—(*Para* 17 128)



Mr Subbaramı Reddy, T —(*Para* 17 129)



Seeth ı_Ramaıah, Atlurı—(*Para* 17.132)



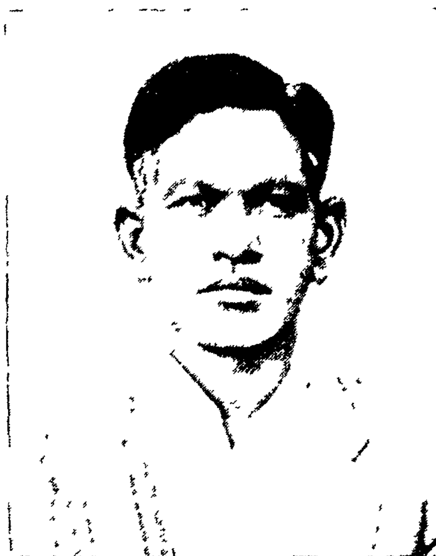
Mr T Yogaıah Naıdu—(*Para* 17 131)



Mr. Chowdary T R —(*Para* 17.134)



Mr. J. C Rishi—(*Para* 17 120)



Late Mr Kunche Satyarayana (*Para* 17 120)

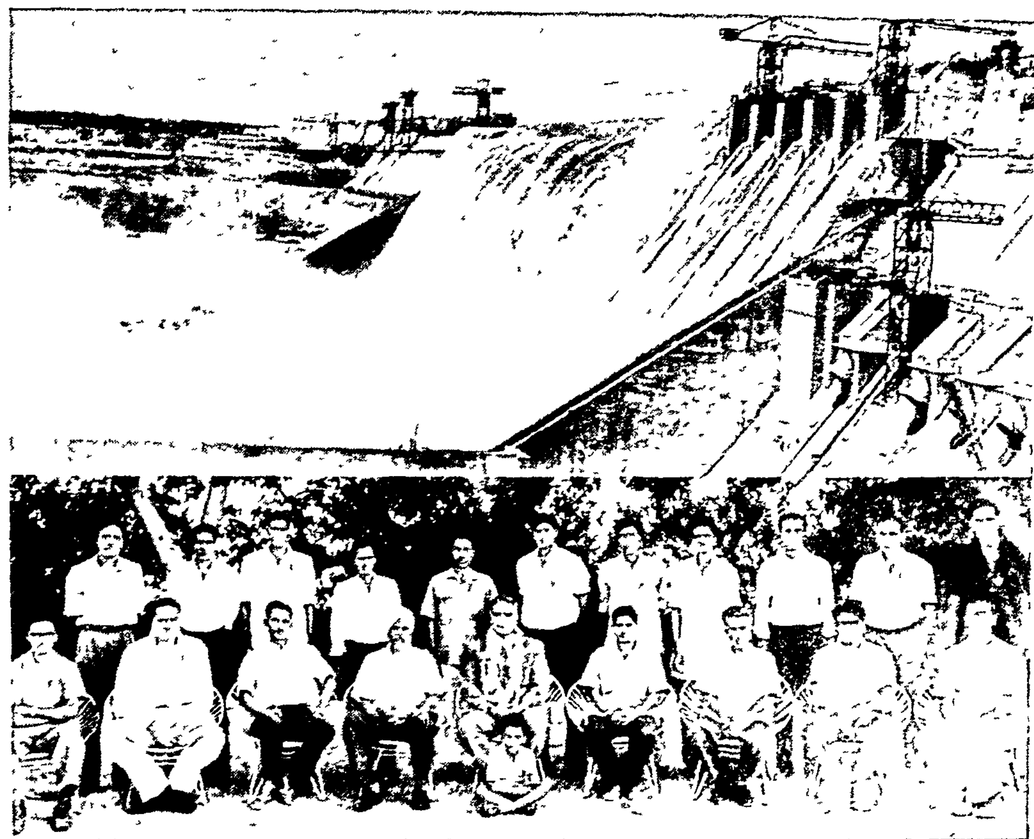


..yanarayana Rao, P —(*Para* 17 130)



Mr Y Rama Rao—(*Para* 17 135)

Staff of Nagarjunasagar Dam, who received Gold Medals from Mrs. Indira Gandhi, Prime Minister of India. on the occasion of letting out water in Jawahar Canal on 4-8-1967.



Work-Charged Employees, Recipients of Gold Medals for outstanding work
(*Para* 17 110)

1st Line Left to Right—Sitting. M Poornachandra Rao, (*Electrician*); M G Naidu, (*Foreman*), M Narasimhamurthy, (*Heavy Machinery*), K. Karam Singh, (*Foreman*), M Gopal Rao, (F I.E.), (*Author*), K Ranga Rao, (*Work Inspector*), V N Bhardwaj, (*Foreman—Cranes*), D Dasarath, (*Machine Shops*), K Anwaruddin, (*Transport*)

Standing K Chanan Singh, (*Foreman—Cranes*), Sitaram Saha, (*Foreman—Winget Batching Plant*), R Chellamuthu, (*Fitter*), K Mallaiah, (*Maistry*), P Gangadhar, (*Master Mason*); S S Raju, (*Crane Operator*), K Subba Rao, (*Maistry*), G Thomas, (*Mason*), Syed Khaja, (*Electrician*), G P Varghese, (*Shovel Operator*); P. V Raju (*Heavy Machinery Operator*)

outstanding work in the construction, at the time of the ceremonial letting out of Nagarjunasagar waters into the canals, by the Prime Minister of India, Mrs. Indira Gandhi. The recipients of these awards are listed below, indicating the merit for which they were honoured:

	Name	*Merit for which awarded*
1.	Mr. Kapu Mallaiah, Maistry, Mortar Supply.	The most efficient and devoted worker in mortar supply.
2.	Mr. K. Subba Rao, Maistry, Dewatering	Excellent supervision of construction works
3.	Mr. M. G. Naidu, Assistant Foreman, Traffic	Top class supervision of mechanical works and traffic control.
4	Mr. P. Venkateswara Rao, Maistry, Shuttering.	Efficient Supervision of field workshop.
5.	Mr. Chella Muthu, Fitter, Track lines	First Class maintenance of light railway lines.
6.	Mr. Sitaram Saha, Foreman, Batching Plants	Excellent operation and maintenance of Winget batching plant
7.	Mr P. V. Narasaiah, Mechanic, Batching Plant.	Prompt repairs of batching plants.
8	Mr. K.Karam Singh, Foreman, Shuttering.	Superb management of field workshop
9.	Mr. K. Ranga Rao ..	Vigilent supervision of shuttering works.
10.	Mr. S. Venkateswara Rao, Maistry, Concreting.	Strenuous supervision of concreting works.
11	Mr. Gangadhar, Maistry, Dam Construction.	Specialist in masonry work.
12.	Mr. Harbansingh, Fitter Shuttering	Excellent shuttering work.
13.	Mr. Ch Nageswara Rao, Mason, Dam Construction.	Outstanding mason.
14.	Mr. V W. Bhardwaj, Foreman, Batching Plants.	Prompt and efficient repairs to batching plants.
15.	Mr. Channan Singh, Foreman, Cranes.	Excellent operation and maintenance of cranes.
16.	Mr Purnachandra Rao, Assistant Foreman (Electrical).	Superb maintenance of electrical installations.
17.	Mr. Syed Khaja, Electrician.	Prompt and efficient electrician.
18.	Mr. Dasarath, Assistant Foreman, Workshops.	Excellent management in running workshop.
19.	Mr. N C. Govinda Reddy, Fitter Craftsman Workshops.	Top class fitter of the workshop.

	Name	*Merit for which awarded*
20	Mr. G M. S. Ali, Welder Craftsman Workshops.	Top class welder.
21.	Mr P. Narayana Murthy, Foreman, Transport.	Brilliant in repairs to transport vehicles.
22.	Mr. Anwaruddin, Assistant Foreman, Transport.	Top class mechanic in repairs.
23.	Mr. P. V. Raju, Driver.	Efficient driver in transport section
24	Mr. Narsimha Murthy, Assistant Foreman, Heavy Machinery.	Top class mechanic in the repairs of heavy machinery.
25.	Mr. S. A. Qayyum, Dozer Operator.	For efficient and excellent performance in dozing operation.
26.	Mr. Verghese, Shovel Operator.	Superb performance in shovel operation.
27	Mr. S. S Raju, Operator, Heavy Machinery.	For maximum output and efficient operation.
28.	Mr. S. Rami Reddy, Lab Assistant.	Efficient Assistant in Laboratory.
29.	Mr. E. Samuel, Drill Operator	Top class in drilling operations.
30.	Mr Irison, Wagon Drill Operator.	Top class operator of Drilling Machines.
31	Mr. Balakrishna, Plumber ..	Accurate and precise plumbing work.
32.	Mr Thomas, Mason .	Efficient mason.

Doctors

17 111 Dr. P. Rami Reddy, was the first Civil Surgeon. He organised the first hospital in the hutments of the labour colony. He had organised the medical unit and prepared plans for a permanent hospital at the Hill Colony He left the project in the year 1957 and was succeeded by the following Chief Medical Officers :

Dr. Ghousuddin ..	.. 1957-1959
Dr. Haricharan Das	.. 1959-1960
Dr. M. Ramasheshaiah	.. 1960-1962
Dr. T. Rangaiah ..	.. 1962-1964
Dr T. Suryaprakasa Rao	.. 1964-1968
Dr. T. B. G. Tilak ..	.. 1968-1970
Dr. C. Papa Rao .	. 1970-1973

17.112 The Chief Medical Officers had rendered great services in the case of accidents and were responsible in saving many lives and limbs.

Dr. Ghousuddin

17.113 The hospital was planned by Dr Ghousuddin. After leaving the project in 1959, he died prematurely in 1960.

Dr. Haricharan Das

17.114 Dr. Haricharan Das was popular for his prompt and efficient surgical operations.

Dr. M. Ramasheshaiah

17.115 Dr. M. Ramasheshaiah served during the crucial stage of construction. During his time, the hospital was expanded with extra rooms, laboratory, X-Ray, etc. He attended to difficult accident cases involving major operations successfully. He took special interest in treating the poor patients.

Dr. T. Rangaiah

17.116 Dr. T. Rangaiah organised Blood Bank and saved many lives by timely blood transfusion and efficient operations His wife Dr Mrs Kamesvari also served as a Lady Doctor from 1962 to 1964. The couple were very kind to the patients It was in his time that the extensions to the hospital were completed The hospital was named ' Kamala Nehru Hospital ' and was inaugurated by Smt Indira Gandhi on 6th December, 1963. He vitaminised the builders working round the clock.

Dr. Suryaprakasa Rao

17 117 Dr Suryaprakasa Rao, joined Nagarjunasagar Dam in August, 1964 He was very popular among the staff and attended to difficult and serious cases personally even during his leisure hours At the time of his transfer from the project, the staff honoured him presenting a silver plate as a token of their gratitude. He was also responsible for the opening of the children's ward inaugurated on 15th July, 1967 by Mr Morarji Desai, Deputy Prime Minister of India.

Dr. T. B G. Tilak

17 118 By the time, Dr. T B. G Tilak took over in 1968, the number of accidents reduced in the dam. But due to his kind treatment and expertise, patients started flowing-in from distant places Even though the dam was practically completed, the patients did not decrease. He was responsible for starting the Well Baby Clinic in the Kamala-Nehru Hospital

Contractors

17.119 The entire masonry work was executed by a number of contractors on piece rate system. Important items of construction such as manufacture and supply of mortar, rubble lifting by monotower cranes, were done by the department. Thus the largest portions of the construction work, were executed by the department which was the chief agency.

17.120 The first contractor of the project was Mr. Khader Sheriff, who built a major portion of the approach road from Peddavura to the site of the dam. He was followed by Mr. Zamin Ali Gazi and Mr. Jagat Narayan Pande. The first and difficult work at the dam site was the construction of the Pylon which was built by Mr. S. K. Iyer, Contractor, a retired Superintending Engineer of the Tungabhadra Project He was followed by Mr M. G. Laxmi Narasu, who started construction of buildings. Mr. Kunche Satyanarayana and Mr. Sagi Ramakrishna Raju were the first contractors who started excavation of the left flank of the dam. Mr. Batra and J. C. Rishi were the first contractors who supplied sand from Pedda Vagu which had no proper approaches. Mr. J. C. Rishi, with his dynamic vision, solved all the problems in sand supplies. They were followed by a number of contractors. Following is the alphabetical list of the important contractors :

Ahmed Yar Khan
Andhra Civil Construction
Balaram Reddy
Chandrasekhar Reddy
Chowdary T. R.
Gammons India Limited
Harbans Singh Harnam Singh
Iyer, S. K.
Jessop and Co
Krishna Rao Kunche
Krishna Rao, V.
Krishna Reddy, G. V.
Laxman Singh Karam Singh
Laxmipathy
Laxminarsu
Magal
Mittal & Co.
Nageswar Rao V.
Narasimha Reddy
National Construction
Puri, K. S.
Prabhat Construction

Premier Construction
Patel Engineering Co., Limited
Prasad Co.
Pioneer Construction Co.
Ramachandra Reddy, G.
Ramakrishna Raju, Sagi
Ramakoteshwar Rao, A
Rama Prasad Private Limited
Rishi J. C.
Satyanarayana Kunche
Sar Raju
Southern Engineering Works
Sri Rama Construction
Subba Rami Reddy T.
Suryanarayana Rao, P.
Supreme Construction
Universal Construction
Vijaya Construction
Yogaiah Naidu T.
Yagnaiah & Sons
Zamin Ali Gazi

17.121 At the time of letting out waters of the Nagarjunasagar Reservoir into canals, the following contractors of the dam were awarded Gold Medals by Mrs. Indira Gandhi, the then Prime Minister of India, for their outstanding work in the materialisation of the project .

M/s. Andhra Civil Construction Co.

17.122 Mr. Ananta Raman and M. J. V. Somayajulu represented M/s. Andhra Civil Construction Co. They had done maximum masonry in the construction of the dam. They had given the maximum progress on crane blocks on the right flank of the dam. Their work was well-organised and well-disciplined during the entire construction The quarries were managed excellently. The Director of M/s Andhra Civil Construction Co., Mr J V. Somayajulu, was in charge of the organisation and played eminent role at various stages of the construction.

Mr. Chandra Sekhar Reddy, T.

17.123 He represented Supreme Construction Company and was responsible for raising the right earth dam from foundation to completion level. He was the first contractor to record maximum progress of masonry during the year 1962.

M/s. Harbans Singh Harnam Singh

17.124 This firm represented two partners, one Sri Harbans Singh and the other Sri Harnam Singh. They were reputed for their efficient

and fast work. They were responsible for raising the most difficult blocks on the right flanks, right from the foundation, practically to the completion level. Their firm built 13,300 cft. of masonry on a single day on block 42 which is the maximum ever done by any contractor on the dam. At the completion of the dam Sri Harnam Singh died in 1970, prematurely.

Mr Krishna Reddy, G. V.

17.125 Mr. G. V. Krishna Reddy, was a young graduate contractor, played an important role in building the masonry. He had organised the most difficult construction of block 11. He had also constructed the most difficult aqueduct of the left canal across the Munair River near Khammam On the 24th of December, 1965 he had built 11,300 cft. of masonry. He played an active role in building the dam.

Mr. Nageshwar Rao, V.

17.126 He represented M/s. Southern Engineering Works who had done masonry and concreting. On 24 12.1965, he had built 21,300 cft. of masonry in blocks 38 and 39 which was the greatest progress ever achieved by any contractor by lifting stones and mortar manually over 200 ft. height. His firm had also built important cross drainage works in Jawahar Canal. Apart from taking keen interest in building the dam, he had constructed the Children's ward in Kamala Nehru Hospital for which he was the main donor.

Mr. Om Prakash Mittal

17 127 The firm of Mr. Om Prakash Mittal namely M/s. Mittal & Co., was well-established and organised. He was responsible for the entire supply of surkhi required for the dam. In addition to the supply of Surkhi, they had supplied a major quantity of the sand required and also effectively contributed in raising crane blocks on the left flank and the left earth dam. On 2.6.1966, they had shown an extra-ordinary progress of 88,000 cft. on a single day on block fed by crane. This was the peak progress.

Mr Rama Krishnam Raju, Sagi

17.128 Mr. Rama Krishnam Raju was a dynamic contractor who efficiently participated in the construction of the dam right from the excavation of the foundation to the completion. He had established high reputation due to his maximum supply of metal for the dam, and was popularly known as the 'Metal King'. On 24.12.1965, he had supplied 1,700 cum. of metal which was the maximum. He participated in the construction of masonry and concrete and in the social and religious activities till the dam was completed, He was the main donor for the

Sree Rama Temple in Vijayapuri North and for the Ramalaya Dharma Sala where free food is served to the deserving.

Mr. Subbarami Reddy, T.

17.129 Mr. Subbarami Reddy was the youngest graduate contractor of the project He started his career as a contractor in Nagarjunasagar dam in the year 1962. By his unceasing efforts and brilliant management, he was responsible for giving the highest annual record of masonry consecutively for five years from 1962 to 1967. He had erected the highest scaffoldings of 260 feet. Besides dam construction, he had carried out difficult works in Jawahar Canal.

Mr. Suryanarayana Rao, P.

17.130 Mr. Suryanarayana had built in record time the right protection wall along the Krishna river on the downstream side of the dam against rising floods. In the year 1965 he had established the highest record of sand supply on 24.12.1965 when he supplied 60,000 cft. in a single day. He was reliable and trustworthy. Unfortunately he died at an early age of 41 years

Mr. Yogaiah Naidu, T.

17.131 Mr Yogaiah Naidu, joined as a contractor after taking the Engineering degree from Mysore University. He was the managing partner of the Premier Construction Company, who did excellent work. His progress of earth work on the left earth dam was extra-ordinary. He worked from 1956 to 1968. He was reputed for his efficiency and speedy accomplishment of works

Mr. Seeta Ramaiah, Atluri

17.132 Mr. Seeta Ramaiah had taken up to contracts after graduating in Commerce from Waltair, Andhra University. His firm Ram Prasad Private Limited built 450 buildings in the townships of the Hill Colony and Pylon Colony in a record time of one year and a half. His partner Sri A. Ramakoteswara Rao was responsible for raising the left flank blocks of the dam right from the foundation to the completion level.

Mr. Zamin Ali Gazi

17.133 Mr. Zamin Ali Gazi was one of the first and the last contractors who started in 1955 and finally ended the construction of masonry of the Nagarjunasagar Dam in 1968 He was the first contractor to erect his tents in the Hill Colony for the construction of approach roads. Remarkable progress was recorded by him in raising the crane

blocks on 18 6.1966 when he had built 14,500 cft. of masonry in a single day on two blocks. This progress is unparalleled in the construction of the dam.

Miscellaneous Services

Mr. T.R. Chowdary

17.134 Mr. T. R. Chowdary played an eminent role in the early stages of the project, as a guide to contractors, labour, engineers and in building the construction bridge across the Krishna river. At present he is the Chairman of Andhra Pradesh State Trading Corporation.

Mr. Y. Rama Rao

17.135 Mr. Y. Rama Rao, Public Relations Officer rendered yeoman services to keep the highest tempo of public relations and information. He worked right from the inception of the dam in 1957 to the completion. He was an excellent liaison between the dam organisation and the public. Along with his Assistant Public Relation Officers, Mr. Raju and Rama Mohan Rao, he maintained the Vijaya Vihar and other Guest Houses, efficiently and to a high standard.

M/s. Mushtaq Ahmed and Gopal Reddy

17.136 The Police Department had to maintain law and order. It was the State Government who deputed the officers to work in close co-operation with engineers. At early stages, M/s. Mushtaq Ahmed and Gopal Reddy, Circle Inspectors maintained discipline and law and order excellently.

Mr. C. V. G. R. Murthy

17.137 In the last stages Mr. C. V. G. R. Murthy, Circle Inspector had done outstanding work. Due to his untiring efforts and vigilant activities, the progress of work could go on uninterrupted.

Mr. S. N. Reddy

17.138 He was the Security Officer (Inspector of Police) who worked in the Project for a maximum period of 11 years from 1960 to 1970. He was in-charge of guarding government materials from pilferage and of general security arrangements. When one of the spans of the bridge across the Krishna river sunk on 30.9.1964 he was the first person to inspect in early hours and he stopped the traffic. Else, due to collapse of some spans, there would have been disastrous consequences.

RESUME

17.139 Nagarjunasagar dam is an outcome of team work of builders from various parts of India, who worked with a spirit of harmony, co-operation and integration. At the completion of the dam, thousands of skilled workers got trained in various trades and the expertise was exported to other parts of India and abroad specially for labour oriented projects

Indeed the number of workers who participated in the gigantic task and contributed to the successful construction of the Nagarjunasagar dam is too large for citation. However, in this chapter an attempt has been made to mention the names of such builders whose sacrifice and services were remarkable. The mention of the names of outstanding builders will not only encourage and honour them at the completion of the stupendous task but also inspire the workers in other national projects. This chapter would also give solace to the family members of the martyrs by perpetuating their memory with the history of the construction of this gigantic national monument and present a record for the posterity to admire for ages.

CHAPTER XVIII

NAGARJUNASAGAR TOURIST CENTRE

Tourism is a means to peace, progress, happiness and harmony and engineers are the builders of the infrastructure to achieve this objective. It is an economic proposition and is not merely a socio-cultural feature. It is also an important industry for attracting foreign exchange. In the case of the Nagarjunasagar dam, having been built with the sweat and toil of the millions of people, with scenic beauties around, it is fascinating for a tourist to see the dam as a magnificent symbol of developing India.

18 2 The Krishna valley had seen the rise and fall of many a famous dynasty, empire, culture and civilisation of which Sathavahana, Ikshvaku, Chalukya, Kakateeya, Kutubshahi and Vijayanagar were some. Hinduism, Buddhism and Jainism, Christianity and Islam, equally flourished on its banks. The glorious history of the river, with the Nagarjunasagar lake, mirrors past history, the present monuments and the future glory. On the banks of the river, apart from the gigantic masonry structure of the Nagarjunasagar dam, are sacred shrines drawing devotees and pilgrims from all parts of India and abroad. The most important of these are Srisailam, Nagarjunakonda, Vedadri, Amaravathi, Vijayawada which have already been described in detail in chapter I.

The Schemes Prepared

18 3 To develop the Nagarjunasagar as an international tourist centre, it was the dynamic Minister for Tourism, Government of Andhra Pradesh, Mrs. Roda Mistry, who arranged a visit of outstanding architects from all over India on July 19, 1970, at Nagarjunasagar in order to improve the architecture of the dam and enhance the tourist infrastructure to international standards. The eminent architects convened a meeting at the site and they inspected the various places along with Mr. P. Vaman Rao, Director of Information, Public Relations and Tourism, Mr. R Grover, Collector, Nalgonda, Mr. T. J. Solomon, Revenue Divisional Officer and Officers of Fisheries and Forest Departments The architects, Messrs. K. A. Siddique, B. B. Puri, Shantilal Dand, Chowla and Raghukula Pershad, participated in the meeting along with Mr. Y. Ram Rao, Public Relations Officer and the Author. This was the first event of its kind when a team of architects and important officials of the dam organisation held a conference at the dam site for preparing blue-prints for the master plan of future development works

for tourism. On this occasion, the author highlighted the important architectural features of the dams in foreign countries he had visited. He impressed upon them specially the significance of coloured lighting of the spillway waterfall of the dam and the chutes. The coloured lighting of water falls of the dam, like the world famous Niagara falls in America, would create scenic beauty and attract tourists

In addition, there are the great Buddhist relics at the dam site. Though the Nagarjunasagar dam is nearly 20 times as big as the Krishnarajasagar, a dam near Mysore in Karnataka, not even a fraction of the tourist attractions created at Krishnarajasagar, has yet been built up at the Nagarjunasagar. In accordance with the deliberations of the meeting with the architects, the Minister proposed various plans such as a Tourist Reception Centre, Cafeteria at the embarkation points of tourist launches and at Nagarjunakonda, development of the tiger valley with parks, swimming pools etc. It is expected that it will not take much time before things take shape. The Tourist Reception Centre and the Cafeteria were established in 1971.

Natural Scenery at Nagarjunasagar

18.4 The lake with a water spread area of 285 sq km and the two canals taking off one on either flank, is a very picturesque scene There is a natural water fall called the Ethipothala fall in the Singarayasala valley only 11 km from dam site Situated between the Jawahar canal and the Krishna, the Ethipothala has a fall of 25 metres and the present meagre water fall could be easily supplemented from the Jawahar Canal by sending a part of the water required for the Krishna delta, from the Jawahar Canal through the waterfall The water will not go waste, as the Singarayasala is a tributary of the Krishna It would suffice if 25 cu.m. of water per second are diverted from the Jawahar Canal in which there is sufficient capacity at the head reach. This water fall, with proper lighting arrangements and the beautiful guest house situated nearby, will be a tourist's plaza

Nagarjunasagar is a tourists' paradise It is a nature's beauty spot for holiday goers, a study spot for technicians, a place of pilgrimage for farmers and peasants and a source of prosperity for the millions of people that inhabit this region. The picturesque valleys are full of greenary The coloured mountains shine like saphires and emeralds with the reflected rays of morning sun and evening sun through the waters of the lake. The blue skies and blue waters of the Krishna reveal the colours of Lord Krishna who was blue in colour

Infrastructure

18.5 The Nagarjunasagar dam is geographically located in the centre of Andhra Pradesh. It is in-between Hyderabad and Madras,

the Capitals of Andhra Pradesh and Tamil Nadu. It is 150 km. from Hyderabad. It has an airstrip and several tourist bungalows, and is well connected by dust-proof roads to these two capitals The Railway terminus of Macherla is 22 km. south of the dam. Along the Krishna river, it is midway of the great pilgrim places of Srisailam and Vijayawada.

Within the environments of the dam area, the Tiger Valley is a nature's gift for the tourist development and has a highly favourable topography for the development of extensive gardens, lawns, parks, kiddies' corners, artificial lakes for boating, fishing, children's railways, high class restaurants, swimming pools of international standards and travelling fountains which were attractively displayed at Expo 70, of Osaka in Japan.

The Tourist Reception

18.6 Driving from Hyderabad, as the tourist enters the dam area, near the water spread of the lake, about 16 km (10 miles) from the dam, he would first be welcomed from his left by the Bangari Gutta (the hill that glitters like gold with the reflection of the sun's rays). Before he enters the township of Vijayapuri North, he is received at the attractive pavilion of the tourist reception centre. This centre provides the information to the tourists for their accommodation and guidance for visiting important beauty spots and places of interest.

Existing Facilities For Tourists

18.7 Following accommodation facilities are available for tourists:

(i) Vijayavihar Guest House with eight rooms. This is air-conditioned. By the side of this is also an air-conditioned Tourist Annexe with eight rooms These two guest houses are located in Hill Colony on the fore-shore of the Nagarjunasagar lake. There are extensive lawns and flowerbeds with a well-maintained garden. The visitor will enjoy the scenic beauty of colourful mountains, the lake with a view of the dam and the flood gates from the upstream side of the dam and the enchanting charm of the morning sun reflecting its coloured rays through the waters of the Lake.

Opposite to Vijayavihar are six two-roomed cottages with separate kitchens for the tourists who wish to prepare their own food.

(ii) In the Hill Colony, within one kilometre of Vijayavihar, is the 40-roomed Project House with catering arrangement. Each room has an attached bath-room.

(iii) On the left bank of the river, two km. downstream of the dam, is the Sethu Sadan Guest House with two rooms. This guest house faces the river and has a picturesque view.

(iv) Opposite to Sethu Sadan, on the right bank of the river, is situated the River View Guest House, with four rooms. This guest house overlooks the downstream side of the dam and has the greatest scenic beauty of the waterfall over the spillway. This guest house had the unique privilege of accommodating Dr Rajendra Prasad, the former President of India and Mr Jawaharlal Nehru, the former Prime Minister of India.

(v) On the right bank of the river, with an attractive view of the lake, is the Lake-View Guest House with two rooms. On the right bank there are two three-roomed cottages for the tourists.

(vi) Apart from the accommodation described above two special Community Halls, with kitchen and bath-room facilities, have been provided, one on each flank of the river, to accommodate poor visitors to the Project.

(vii) On the Nagarjunakonda, the Government of India have provided a Guest House with four well-furnished rooms for the tourists.

(viii) On the Nagarjunakonda, we have also guest houses, built by the Government of Andhra Pradesh for the middle income group visitors and also for common people.

(ix) Apart from the above, there is a Dharmasala (free guest house) attached to Sri Ramalaya Temple. This Dharmasala has two rooms with facilities for cooking and bath-rooms. Free food is served here to deserving and needy visitors.

Within a minute after leaving the reception, while driving towards the dam, the visitor would see the Vijayavihar Guest House on the right and the Saint Joseph's convent school on the left. On the same road after a minute, he would find the temples of Satyanarayana Swamy, Madhava Swamy, Eleswara Swamy and Hanuman. The idols of Madhava Swamy and Eleswara Swamy were brought for rehabilitation from the submerged area of Nagarjunasagar.

The Pylon

18.8 As the tourist drives from the left flank over the dam, he will first see the beautifully engraved pink coloured and polished granite

stone pillar called the pylon, depicting the past glorious civilisation of the place, the present construction and the future prosperity of India in its manpower and agriculture.

The pylon, located on the axis of the dam, is a granite piece of architecture with a height of 10.75 metres. It is standing on a high ground separating the masonry dam of Nagarjunasagar from the left earth dam. It has a lotus as its base, Purna Kumbha at its apex and with sculptures on each of the four faces. On the faces the sculptures are of Nagarjunacharya (the great Buddhist scholar and a saint), the Dharma Chakra of Ashoka, the manual operations in the dam building and a peasant with a pair of his bullocks, which are the backbone of Indian economy On the top of the Pylon is the Purna Kumbha, signifying a nectar of water being stored by the great lake of Nagarjunasagar reservoir. The Purna Kumbha is also the emblem of Andhra Pradesh State.

The pink coloured granite stone Pylon has been given high polish. These stones, brought from Asafnagar quarries near Hyderabad, are a rare variety From these quarries stones are exported to other countries for architectural features.

To mark the inauguration of the Nagarjunasagar Project, the Pylon was unveiled by the Prime Minister of India, the Late Mr. Jawaharlal Nehru on 10th December, 1955.

Visit to Ancient and Modern Temples

18.9 Three hundred metres north of the Pylon are situated Sri Ramalaya and the Kanaka Durga temples of Hindu architecture, which a visitor should not miss. Close to these temples is the Sri Ramalaya Dharmasala.

In the same area are situated a modern mosque built by Mr. Zamin Ali Gazi, and a modern Church built by Father L Pezzoni.

Before driving over the gigantic structure of Nagarjunasagar dam, named as modern temple by Mr. Jawaharlal Nehru, the tourist is advised to glance at the model of the Nagarjunasagar dam which has been built 200 metres to the west of the Pylon. The model, built as a running one, gives a complete picture of this great monument and its surroundings.

As the tourist drives over the top of the masonry dam, he would halt at half way for a while. Standing on the dam, he admires the miles and miles long stretch of the serpentine course of the Krishna river, by a look over the downstream side. The mighty river, which once was flowing as an unquestioned monarch, creating problems of flood, has been tamed for the benefit of humanity. Looking towards the upstream side, the visitor would be thrilled by the expanse of the blue waters touching the skies at the horizon with the endless waves welcoming the guests.

Over the dam, the tourist will particularly note the parapet walls of the dam depicting the railings of the Buddhist architecture which has gone under the submergence of the Nagarjunasagar lake. When the tourist alights on the road at half way of the spillway, he will find himself flanked at either end by the beautiful elevated and majestic utility towers. These were designed as the masterpieces of Buddhist architecture of Nagarjunakonda by the famous architect of Hyderabad, Mr. Prem Dass. The visitor will then step into the utility towers, from where he can go into the body of the dam to the various galleries by electric lift. With previous permission the visitor would be conducted to the visitor's gallery situated at 420 feet level. When he continues his journey towards the end of the dam, he will meet a second Ramalaya (temple) in Vijayapuri South. The temple has its idols similar to those at Bhadrachalam temple.

The tourist will then go to Anupu which is at a distance of 11 km from the dam, where boats are arranged to visit the Nagarjuna Island Museum, which is the only one of its kind in the world. At Anupu, a Cafeteria has been built in Buddhist architecture.

Before reaching the museum, while in the boat, the tourist will see to his west the Simha Giri (The Lion Hill) on which are situated ancient temples.

Embarking from the boat at the Nagarjunakonda Hill, the visitor will proceed to the Nagarjunakonda Museum.

Historic Museum of Nagarjunakonda

18 10 The construction of Nagarjunasagar Dam, has submerged the valley of Nagarjunakonda which was the seat of Mahayana Buddhism propagated by saint Nagarjunacharya, in the second century A.D. During this period, the city of Vijayapuri, situated in this valley, was the capital of King Chantamula of the Ikshavaku dynasty of Ramayana fame. The precious monuments of sculptures and other relics of this historic city have been transplanted and preserved in the island museum of Nagarjunakonda. A flourishing neolithic tool industry and palaeolithic tools were unearthed in the excavations of the valley and they have been housed in the museum. These widen the archaeological horizon of this valley, giving a fairly correct account of the achievements of the prehistoric man in this part of India.

The Relic of the Buddha

18.11 When the Buddha passed away, his ashes were sent to all the Asian countries and his tooth was sent to Nagarjunakonda valley where it was ceremonially buried in a gold cup with Pancha Ratnas, (five precious stones) and a gigantic Mahastupa was built over it. When the Mahastupa which was going under submergence was excavated, this precious relic in the gold cup was recovered. A part of this relic has been shifted

to Sarnath near Varanasi and is now being worshipped in the Moolagandha-Kuti Vihara where the Buddha delivered his first sermon. At the Museum, monuments like bathing ghats, the Asvamedha altar, the Mahastupa and the Simhala Vihara have been reconstructed on the top of the hill.

At the entrance of the Nagarjunakonda Museum, there is a beautiful statue of the Buddha. This is similar to the one at the entrance of the American National Museum at Chicago where a sculpture of the Buddha taken from India, forms a focal point of the entire museum.

The Nagarjunakonda museum has become a centre of interest drawing tourists and scholars from near and far off lands, reviving the rich old traditions of Nagarjunakonda. The dam and the museum are now attracting more than 35,000 tourists from all over the country and abroad every month. The visitors range from farmers to foreigners and from village folk to very important personnel.

Visit to Ethipothala Waterfall

18 12 At a distance of 11 km. from the dam site are the Ethipothala waterfalls. There is a good tourist bungalow on the left flank of the waterfalls. Down below the waterfalls is the ancient temple of Ranganatha Swamy with an exquisite sculpture.

Visit to Srisailam

18 13 The famous Srisailam temple with the Jotir Linga is situated on the right bank of the Krishna river 100 km. upstream of the dam. If a traveller wishes to go by road, the distance is 195 km. With the development of tourist traffic, regular high speed Diesel launches have been arranged in the lake of Nagarjunasagar. These launches travel at a speed of 50 Km. per hour.

A large hydro power complex is under construction at Srisailam, downstream side of the Patala Ganga gorge of the Krishna river.

Recommendations for Development

18 14 India has to make great strides in the development of tourism, even though it enjoys obvious advantages for tourism in its rich historical and architectural heritages. Against 220 million annual international tourists—counted by arrivals—India's figure is a trifle, being 0.41 million Its earning from tourism, estimated at less than Rs. 700 million, hardly adds up to one per cent of world earnings. Italy earns as much as Rs 10,000 million every year. It is, therefore, essential to take a look at India's vast natural resources and improve the infrastructure for the development of tourism at places like Nagarjunasagar. The following recommendations are offered for the development, with special reference to Nagarjunasagar.



Vijaya Vihar Guest House—(*Para* 18 7)
(Vijayapuri North)

A Panoramic view of the Nagarjunasagar Dam, Spillway—(*Para* 18 9)



The Great Buddhist Scholar and Saint—(*Para* 18 8)

(*a*) Proper publicity has to be given for the relic of the Buddha preserved in the gold cup which should be kept open for display to all visitors. This priceless relic will attract tourists especially from all over the Buddhist countries.

(*b*) For conducting the tourists, there should be trained guides dressed in Buddhist robes, who could explain in different languages. Help from tape recorders should also be taken specially to explain the Jataka stories of the Buddha depicted in the sculptures in the museum

(*c*) To make Nagarjunasagar an International Tourist Centre, several infrastructure facilities should be increased and those already existing have to be properly maintained The existing accommodation consists of two V.I.P. Guest Houses, Vijayavihar and Tourist Annexe with 8 rooms in each, the Project House with 40 rooms, the Lake View Guest House with two rooms, the Sethusadan with two rooms and the river view guest house with four rooms With the increase in tourists traffic, many buildings at Nagarjunasagar, built for the officers during the construction period, could be converted into tourist cottages Guest houses built at Nagarjunakonda museum require particular attention for housing the tourists for night halts. Two motor launches are available for ferrying the tourists in the lake An attractive view point has been built on the left bank of the dam and important exhibits of construction and technical features are displayed for information of the students, tourists and the public.

(*d*) On the left bank, a 1/100 scale running model of the dam with its canal system has been built. This has to be properly lighted in colours. A pavilion has been built in the foreshore of the lake at Anupu where the tourists embark into motor boats to visit the museum This has to be provided with a modern canteen. Many more facilities will have to be built as the tourist traffic increases.

(*e*) By the side of Nagarjunakonda island, there is another island with an area of 162 hectares at the same level. It will have to be developed as a holiday resort with greenary, sport grounds, musical fountains, Indian dance theatres and meditation centres displaying themes, heritage and culture of India.

Full tourist information guide with colourful illustrations has to be printed and supplied to every touirst at the Reception Centre. A regular tourist industry with adequate infrastructure has to be planned, since this will play a vital role in tourist attraction.

Nagarjunasagar in the Tourist Map of the World

18.15 The Nagarjunasagar and Nagarjunakonda museum have to find a prominent place in the tourist map of the world. It may

be said that Indian tourism has to grow fast. Eventhough the population of India is as much as a quarter of the world, her share of world tourist trade is no more than 1½% It is, therefore, necessary that important tourist attractions have to be developed in India. Mostly the foreign tourists visit Delhi, Jaipur, Srinagar, Agra and get back home. This northern axis will have to be connected with the southern sector which will cover from Delhi, Bombay to Aurangabad, Hyderabad, Nagarjunasagar, Srisailam, Tirupathi and Madras. The air route will have to terminate at the International air port at Madras. All the airports along northern and southern axis should be developed to be capable of handling modern jets.

Tourist Attractions

18.16 Along the routes described above, travel by air, rail and road has to be developed to a great extent. The surfaces of the roads have to be greatly improved and trees will have to be planted on either side of the roads. The tourist should be provided with all the needs such as fuel stations, service stations, resting camps, hotels, motels, wayside restaurants, drive-in restaurants, etc. The tourist should carry back home deep impressions of India, its natural scenery, scenic beauty, historic monuments, cultural contacts and its secularism and brotherhood.

Display of Glories of Nagarjunakonda

18.17 To propagate the image of the hospitality, affection and friendly nature of the people of India, it is necessary that the State Government and the Government of India organise special cultural programmes in places like Nagarjunakonda, so that local tourists and foreign tourtists may come in contact and propagate the great cultural heritage of India in countries abroad. Buddhist history and the glories of the past of Nagarjunakonda have to be displayed at the museum by Son-et-lumiere i.e., by sound and light as displayed at Red Fort, New Delhi and Gandhi-hill, Vijayawada Conducted tours should be organised and adequate arrangements should be made for night halts of tourists for which rest houses with many rooms have already been built at Nagarjunakonda.

Tourist Shopping

18.18 Elaborate shopping arrangements must be made for tourists coming to Nagarjunasagar. Mementos, toys, clothes and fancy goods from cottage and small scale industries require to be made available to foreign tourists, so that they could be carried as presents when they get back. Among the various items of purchase may be included replicas

of Nagarjunakonda sculptures, Indian silk, handloom fabrics, handicrafts and curios Increased sanitary amenities will have to be provided eliminating dust, and sub-standard quality of boarding and lodging

Tape Recorders

18.19 Tape recorders have to be provided in the museum of Nagarjunakonda By the push button system, the tourists should hear explanations at various exhibits in different languages. The tourist guides, dressed in saffron coloured robes, should be selected from Buddhist monks, who have the privilege of preaching Ahimsa (Non-violence) in India and far-off countries.

RESUME

18.20 The sacred centre of Nagarjunasagar which once propagated the message of love and Ahimsa of the Buddha to the people of the world, is now resplendent with its vast lake radiating its widespread canal system, eradicating the poverty of Andhra Pradesh and exporting food grains. This colossal national monument will stand for generations to come as a mighty manifestation of Man's ingenuity and effort. It will inspire the present generation and the posterity for the accomplishment of bigger and greater tasks for harnessing natural resources for people's prosperity. Let the people of this land of scenic beauty, with its historical and architectural heritages and with its fountain head of peace and prosperity attract visitors from far-off countries to sing the Persian Couplet :

'Gar firdos bar ruye zamin ast,
Hamin ast, hamin ast, hamin ast.'

'Be there a paradise on earth,
It is here. It is here. It is here'

ALPHABETICAL INDEX